openLCA 1.4

Comprehensive User Manual

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1 Introduction

1.1 Introduction to openLCA

openLCA is an open source software for Life Cycle Assessment (LCA) and sustainability assessment. It has been developed by GreenDelta since 2006 (www.greendelta.com). As an open source software, it is freely available, without license costs (www.openlca.org). The source code can be viewed and changed by anyone. Furthermore, the open source nature of the software makes it very suitable for use with sensitive data. The software as well as any models created can be shared freely, as long as the database license allows it. openLCA can be used for a number of different applications, for example:

- LCA, Life Cycle Costing (LCC), Social Life Cycle Assessment (S-LCA)
- Carbon & water footprints
- Environmental Product Declaration (EPD)
- United States Environmental Protection Agency (EPA) Design for the Environment label
- Integrated Product Policy (IPP)

This text focuses on the 1.4 version of openLCA. It explains how to carry out the first steps in working with openLCA such as installation and importing databases. This document then provides an overview of openLCA operations and features including descriptions of how to use them.

www.openLCA.org offers many different services to openLCA potential and current users. The website provides links to download the software, the source code, the openLCA LCIA (Life Cycle Impact Assessment) Method Pack, case studies, and user manuals, among other things. There are also links to instructional videos and documents in the "Learn more" section (www.openlca.org/learnmore). The openLCA forum (www.openlca.org/forum) is a useful tool to find out more information. Furthermore, the openLCA team manages a twitter account (@openLCA) and a LinkedIn group (openLCA: free, professional Life Cycle Assessment (LCA) and Footprint software) to keep users up-to-date on news and recent developments.

1.2 Introduction to GreenDelta

GreenDelta was founded by Dr. Andreas Ciroth in 2004. Since the beginning, the core idea has been to provide life cycle-based consulting to businesses world-wide. GreenDelta has been developing openLCA since 2006. We continuously improve the software, expand its features and capabilities and keep it up-to-date with current LCA practice. We are at the forefront of LCA knowledge, offering specialized features such as regionalized LCIA as well as the ecoinvent 3.1 database. Next to software development, GreenDelta also offers Sustainability Consulting services such as guided case studies, research, critical reviews, EPDs and data management solutions. GreenDelta has an international reputation for pioneering professional yet free open source solutions for LCA and for our role as a common denominator in the international LCA community.

1.3 Introduction openLCA Nexus

openLCA Nexus (https://nexus.openlca.org) is an online repository for LCA data. It combines data offered by world-leading LCA data providers such as the ecoinvent centre (ecoinvent database), PE International (GaBi databases), and the Joint Research Centre from the European Commission (ELCD database).

Datasets provided in Nexus can be easily imported into the openLCA software. openLCA and Nexus databases share a common set of elementary flows and other reference data which have been harmonized in coordination with the respective data providers to overcome methodological differences, for example concerning the modelling of waste.

Nexus contains free and "for purchase" data sets. For ordering and downloading databases from Nexus you need to sign up using a valid email address. The procedure here is very similar to a webshop: simply add the database into a shopping cart, and order it. To find out more on how to download databases from openLCA Nexus and import them into openLCA, please see Section 4.3.

The Nexus website contains a powerful search engine for LCA data that allows you to search for data sets in Nexus. It is also possible to filter data sets by the data provider, location, category, price and year of validity. We hope this makes it easy to identify the LCA data that you need.

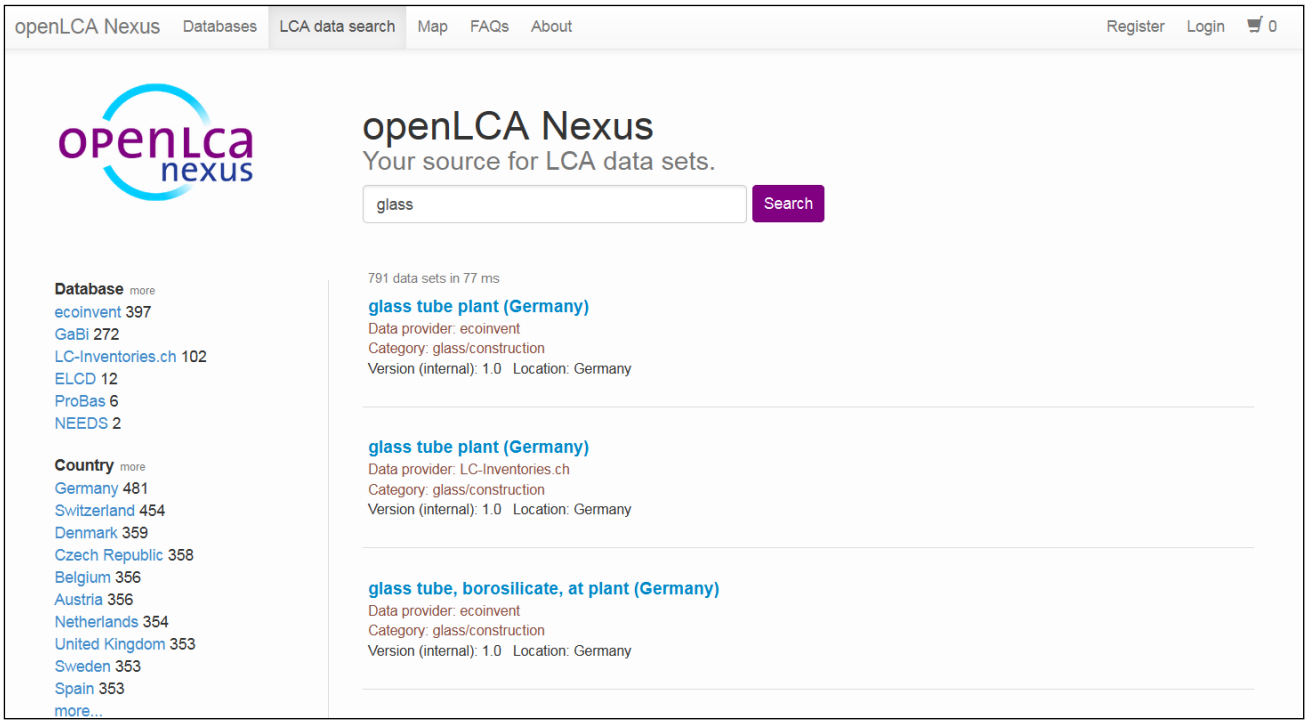


Figure 1: openLCA Nexus search engine

2 Installation

The installation of openLCA is slightly different for Window, Mac and Linux, respectively. The following sections will explain how to install the software on different systems.

2.1 Installation, Windows

For windows, 64 bit and 32 bit versions are available. For the installation, you will need administrator rights.

Hardware, required:

- CPU with 2 GHz or higher
- 1 GB RAM (for analysing product systems with ~2,500 processes, such as ecoinvent 2)
- >3 GB RAM (for analysing product systems such as ecoinvent 3)
- 500 MB free hard disk space + space for databases (e.g. ecoinvent 3 requires ~250MB)

Software, required for the "Projects" feature:

- Windows 64 bit (for modern browser support): Microsoft Visual C++ 2010 Redistributable package (x64) (http://www.microsoft.com/de-de/download/details.aspx?id=14632)

Start by downloading the correct file from the downloads page of the openLCA website. As usual in Windows installation, you can select whether openLCA should be used only by the user who installs (i.e. by you), or by anybody working on the computer (Figure 2).

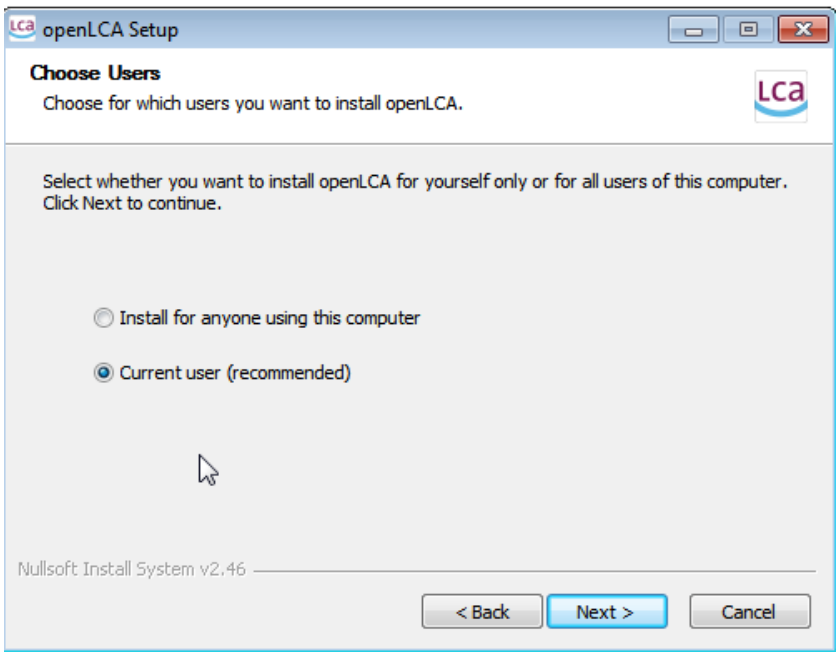


Figure 2: Setup screen for installation in Windows

Follow the installation steps to the end and you can begin working with openLCA

2.2 Installation, Mac

A 64 bit version is available for Mac OS.

Hardware, required:

- CPU with 2 GHz or higher
- 1 GB RAM (for analysing product systems with ~2,500 processes, such as ecoinvent 2)
- >3 GB RAM (for analysing product systems such as ecoinvent 3)
- 500 MB free hard disk space + space for databases (e.g. ecoinvent 3 requires ~250MB)

Software, required:

- Java in version 8; install Java before beginning with the openLCA installation (Java SE Development Kit for Mac OS available under http://www.oracle.com/technetwork/java/javase/downloads/jdk8-downloads-2133151.html).

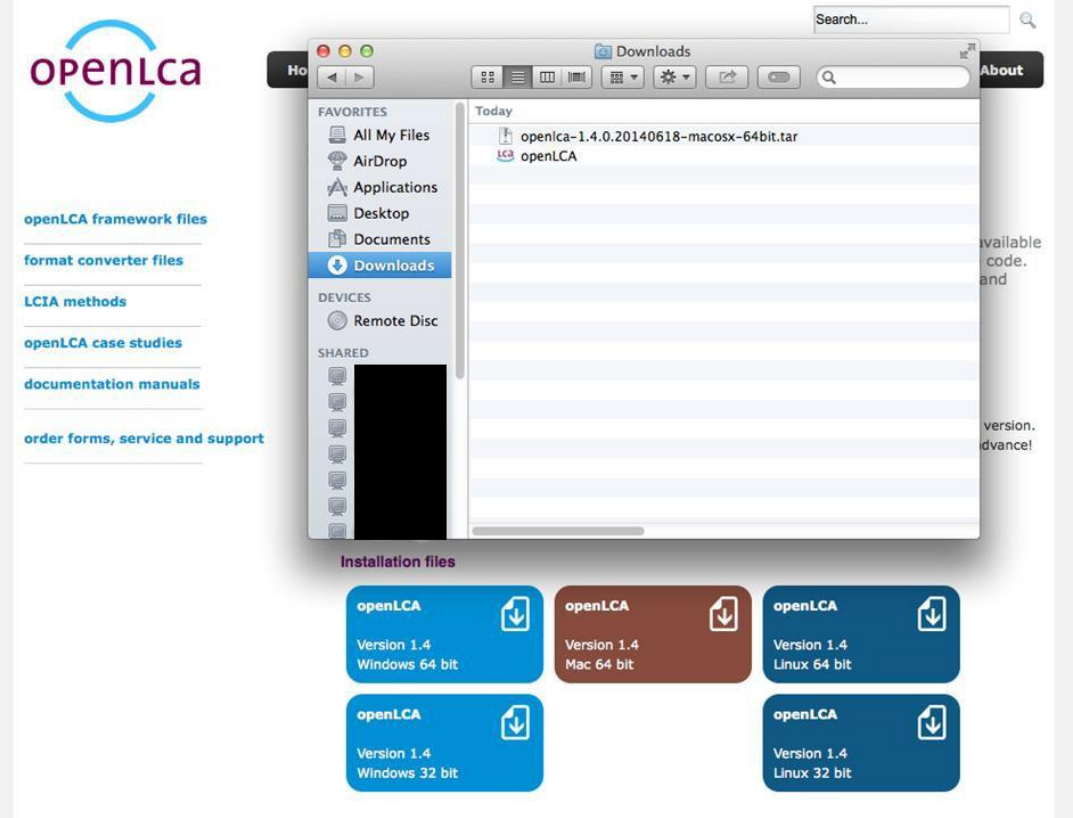


Figure 3: Installation file for Mac OS

Start by downloading the correct file from the downloads page of the openLCA website. Once the download is complete find the program in the "Downloads" folder (Figure 3) and transfer it into "Applications". Double-click on the program to open it. A warning message will appear because the application was downloaded from the internet and not from the App Store . Select "open". This message will only appear the first time you open the program.

2.3 Installation, Linux

For Linux, a 64 bit version is available.

Hardware, required:

- CPU with 2 GHz or higher
- 1 GB RAM (for analysing product systems with ~2,500 processes, such as ecoinvent 2)
- >3 GB RAM (for analysing product systems such as ecoinvent 3)
- 500 MB free hard disk space + space for databases (e.g. ecoinvent 3 requires ~250MB)

We recommend installing libgfortran3 for high performance calculations.

3 Welcome to openLCA

When you start openLCA for the first time, it does not contain any data. On the left hand side you see an empty Navigation field. On the right you see the Welcome page in the so-called "Editor".

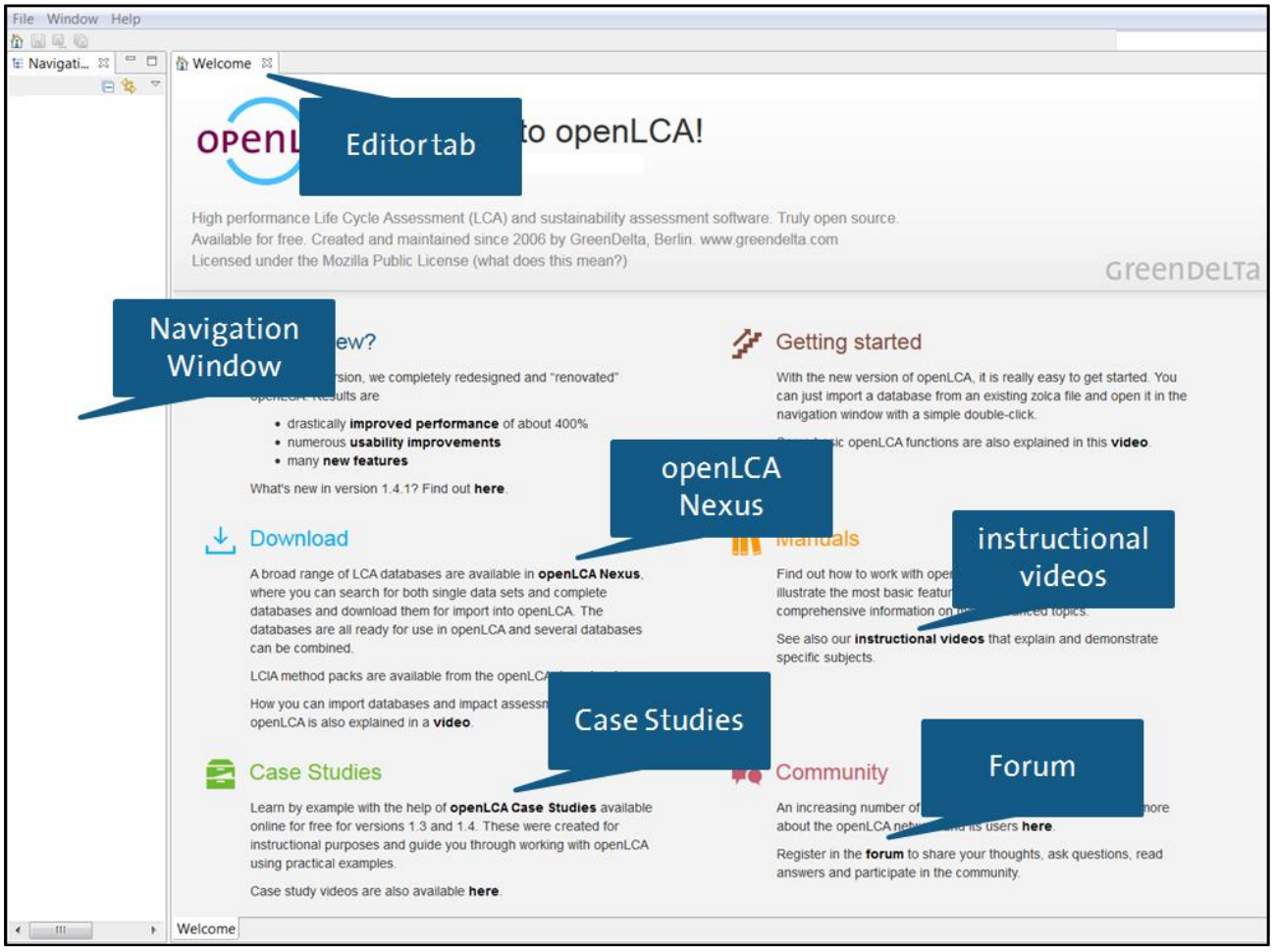


Figure 4: openLCA Welcome page

The Welcome page provides quick links to openLCA Nexus, instructional videos, case studies, this user manual, the openLCA download page where you can download the latest version of the software as well as LCIA methods and, finally, a link to more information on the openLCA network and its users.

3.1 Main menu functions

The following options are available under "File":

- "Save" / "Save As..." / "Save All": save current work open in editor tabs
- "Close" / "Close All": close the current/all windows open in the editor.
- "Preferences":
  - Configuration: select one of the seven available languages you would like to work in (Bulgarian, Chinese, English, French, German, Italian or Spanish). Here you can also select the maximum memory usage. It is recommended to increase this value for calculating very complex product systems (e.g. to ~4,000MB). This feature does not work for Mac OS. If you would like to expand your memory on a Mac OS operating system, please see Section 11.1. Please note: you need to restart openLCA to activate configuration changes.
  - Experimental features: experimental features are features that are still in the beta stage of development but we want to make them available to you and welcome any feedback.
  - Field Assist: This page controls the decorations used in the chart builder dialog.
  - Global parameters: here you can set global parameters, i.e. parameters which apply to all datasets within your active database. To find out more about global parameters, see Section 8.2.2.
  - ILCD Network: Set ILCD Network URL, User and Password.
  - Locations: add/edit geographical information.
  - Logging: Set logging settings.
  - Number format: Set the number of decimal places for numbers displayed.

- "Import" / "Export": For more information on openLCA Import and Export options, see Section 4.2 and Section 4.6, respectively.

The following options are available under "Window":

- "Show Views": Select views such as the Console, Outline, Palette, Properties or Navigation.
  - The Console displays the log
  - The Outline displays: a list of all the processes of a product system, including all its background processes. It is only applicable after you've created a product system. Open the product system's Model Graph (tab) and choose the "Outline" option from "Views". The outline allows you to choose the processes you wish to show or hide from the Model Graph.
  - The Navigation window displays the databases you have imported into openLCA and all the data sets they include.
- "Developer Tools": (to find out more details on scripting in openLCA, see Section 11.2)
  - SQL: SQL is a tool that can be used to carry out enquiries in openLCA.
  - JavaScript: With version 1.4.1, openLCA now supports the possibility to run JavaScript

programs directly in openLCA. With this feature you can automate calculations in openLCA, write your own data imports or exports, perform sensitivity analysis calculations by varying parameter values, and much more.

- Python: With version 1.4.1, openLCA now supports the possibility to run Python programs directly in openLCA. With this feature you can automate calculations in openLCA, write your own data imports or exports, perform sensitivity analysis calculations by varying parameter values, and much more.

- "Formula interpreter": Complex formulas for parameters must be typed in using the correct format. Use this interpreter to check if your formulas are correct. Start by opening up the formula interpreter and then type 'help' to display the help message (Figure 5).

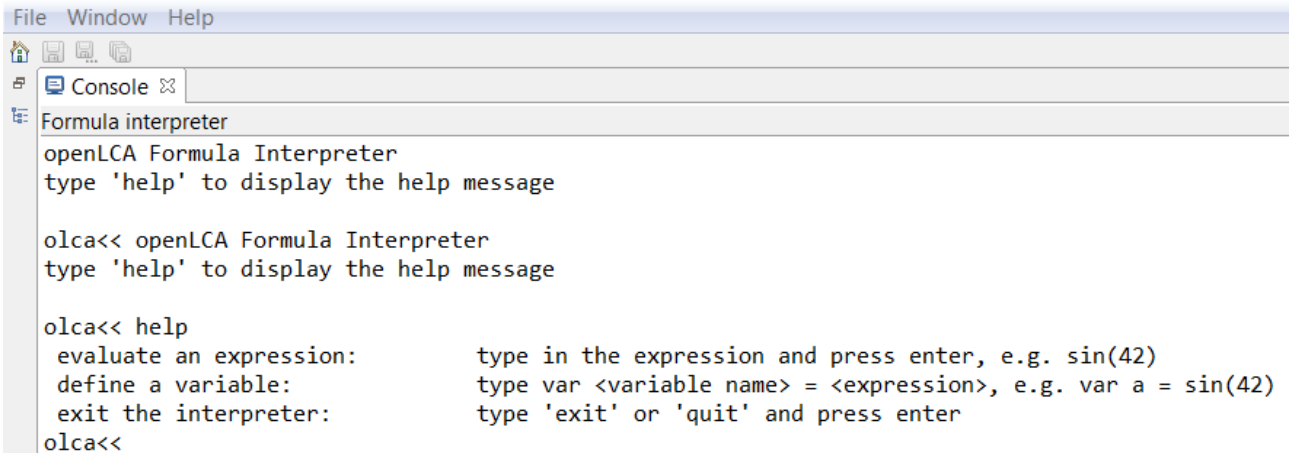


Figure 5: openLCA Formula Interpreter

Under "Help" you can find information on the openLCA copyright as well as a link to this user manual.

4 Databases

Following installation openLCA does not contain any data, therefore the ‘navigation’ section on the left is empty (Figure 6). It is possible to have more than one database. Databases are independent of each other and only one database is "active" at a time. All of the others are "inactive". It is also possible to combine databases (Section 4.4)

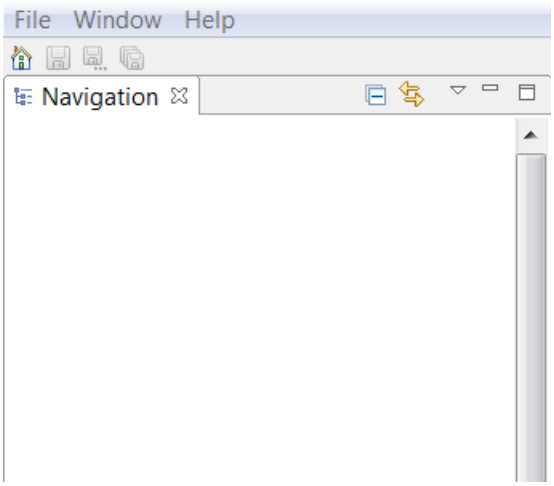


Figure 6: Empty Navigation window following openLCA installation

To change this, you can either:

- Create a new, empty database, or
- Import an existing database.

4.1 Creating a new, empty database

Right-click in the navigation window and select "New database":

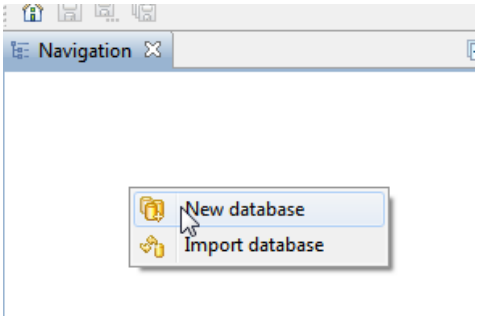


Figure 7: Creating a new database, step 1

The data creation wizard will then appear where you can select your settings for the new database:

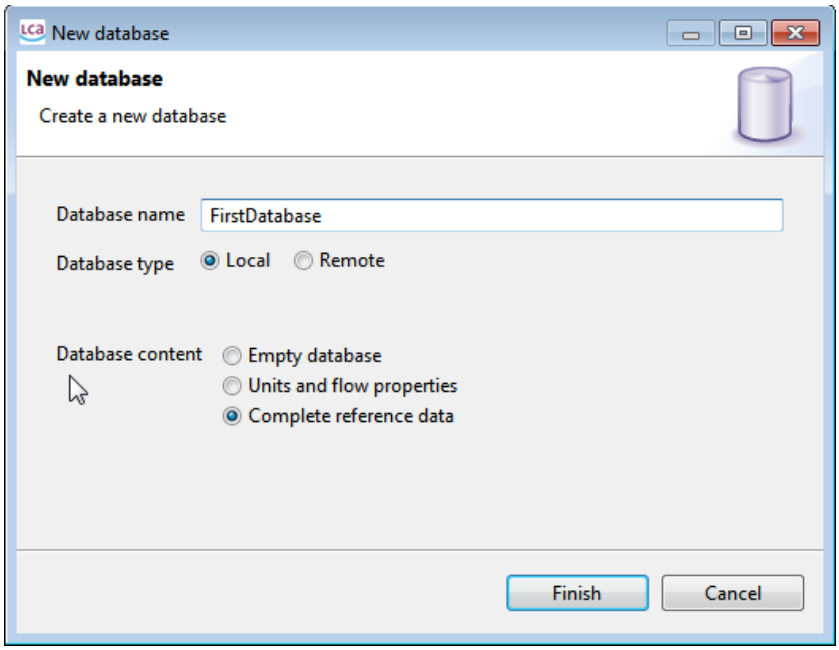


Figure 8: Creating a new database, step 2 (data creation wizard)

For the beginning, it is recommended to create the database with the settings ‘local database’ and ‘complete reference data’. Then select "Finish". After a few seconds, you can have a look at the newly created database:

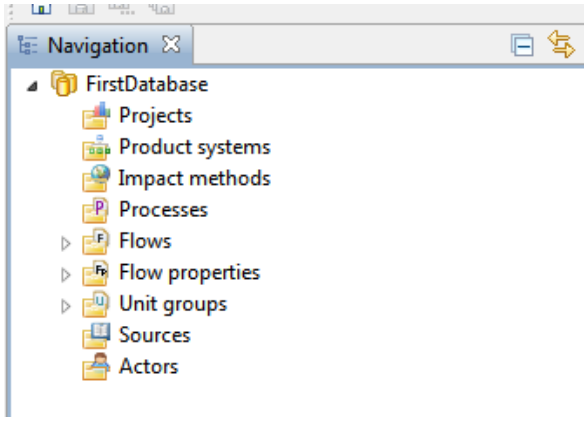


Figure 9: New database containing openLCA reference data only

The elements of the database will be familiar to you if you have worked with previous versions of openLCA. They will be explained in more detail in Section 4.7.

The openLCA reference database contains elementary flows, flow properties, and units. All of the databases available in openLCA Nexus are mapped to ensure that the software recognizes and applies all elements of each database correctly (for example, to ensure no double flows are created during import and that the impact assessment methods available deliver correct results).

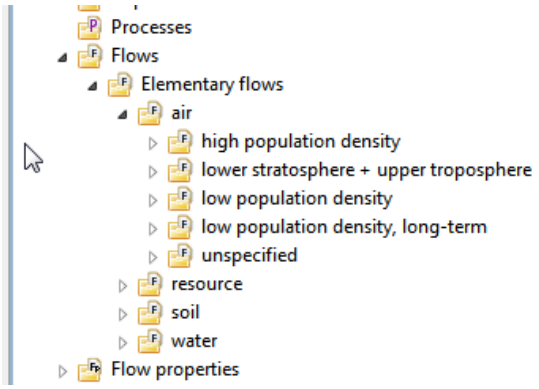


Figure 10: openLCA reference data

This database does not contain any process data sets. You can start creating your own processes using the flows and units that are already present.

4.2 Importing an existing database

As a second option, next to creating a new empty database, you can import an already existing database – either directly into an existing database or as a new separate database. Databases can for example be a database downloaded from the openLCA Nexus website. All of the databases available in openLCA Nexus are mapped to ensure that the software recognizes and applies all elements of each database correctly (for example, to ensure no double flows are created during import and that the impact assessment methods available deliver correct results).

openLCA supports the following import formats:

- zolca
- Ecospold1
- Ecospold2
- Excel
- ILCD
- SimaPro CSV

4.2.1 Accessing databases from openLCA Nexus

As mentioned in Section 1.3, openLCA Nexus (https://nexus.openlca.org) is an online repository for LCA data. Nexus contains for free and for purchase databases. You can browse through the content of the offered databases using the search engine in the sections "LCA data search" and "Map". Using the LCA data search feature, you can search for specific data sets according to name or category (i.e. database, country, other location, Type of data, Category, Price and Start of validity). The openLCA Nexus Map is interactive and illustrates how many data sets are available in different locations. The darker the shade on the map, the more data sets are available for that region. The search can also be reduced by name and by type.

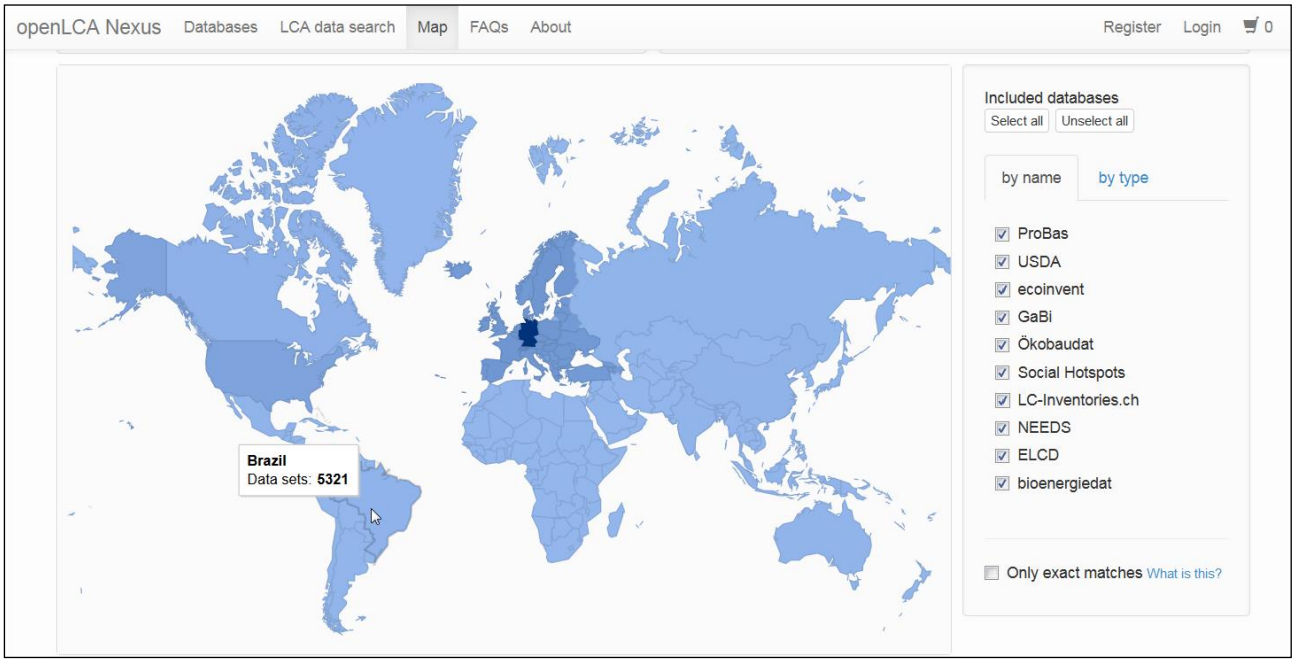


Figure 11: openLCA Nexus Map

To download a database from the openLCA Nexus site you need to first order it. Some databases in openLCA Nexus are available for free and some for charge. To order a database, begin by registering an account.[2] Once you are logged in, go to the "Databases" section and select the license you are interested in. Then add the license you want to purchase to the cart and order it. To find out more about licenses and how to place an order in openLCA Nexus, please see the website's FAQs.

Once you have made an order and it is approved, you can download the database in the "Downloads" section which will appear in the top right-hand corner of the Nexus website when you are logged in. In this section, you will see all of the data files available to you for download. Select the files you would like to download as well as the format (e.g. openLCA 1.4). Once you have read and agreed with the licenses and the EULA, check off the two boxes at the bottom, then select "Download" (Figure 12).

Figure 12: Downloading a database from openLCA Nexus

[2] Registration is quick and helps us to understand and meet the needs of the user base. We are bound to our high data protection principles and protect your privacy.

4.2.2 Importing a database in zolca format

Once you have a zolca file saved on your computer, you can import it directly to openLCA. To do this, right-click in the navigation window and select "Import database":

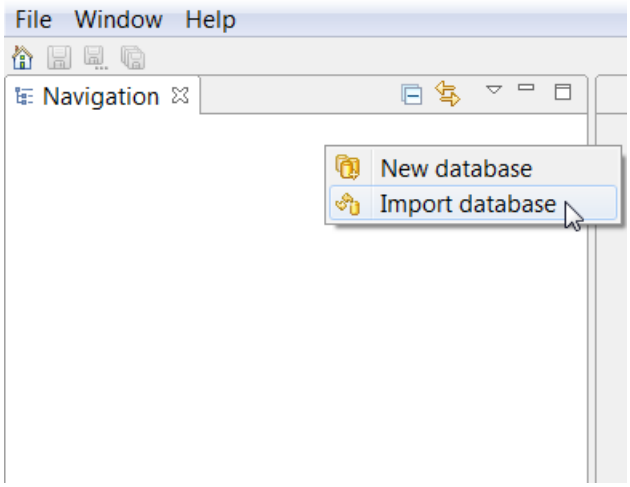


Figure 13: Importing an existing zolca database

Then find the 'zolca' file you would like to import in your browser and select "Open". The database will be 'inactive' at first. To activate a database, double-click on it. Then you will have access to all the flows, processes, etc. the database contains.

4.2.3 Importing databases in ecospold1, ecospold2, excel, ILCD and SimaPro CSV formats

These file types can be imported into existing openLCA databases. If necessary, create a new, empty database. Before importing, double click on the target database to activate it. Then go to "File" --> "Import" --> select file type --> select import file(s) from directory --> check and assign units (only necessary for ecospold 1 and 2) --> select "Finish" to import the data (depending on the data, the import can take a couple of minutes). Note: databases in ILCD format must be imported as zip files.

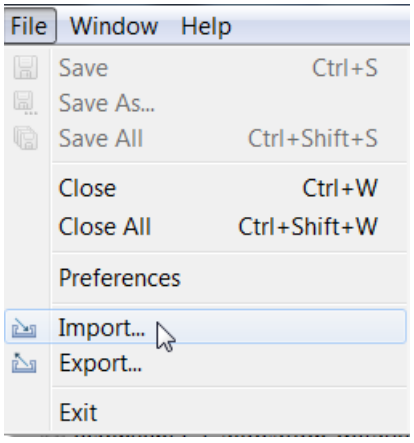


Figure 14: Importing an ILCD database, step 1

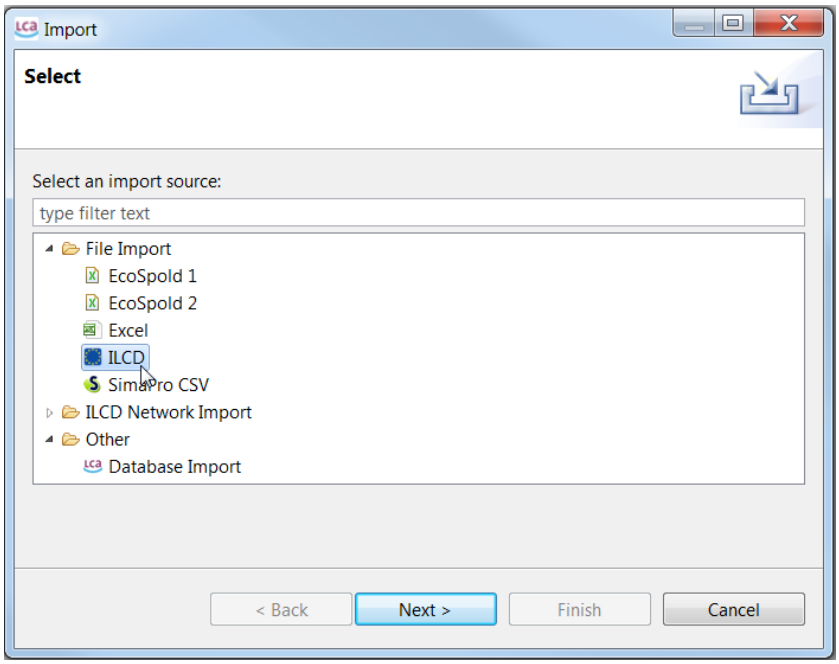


Figure 15: Importing an ILCD dataset, step 2

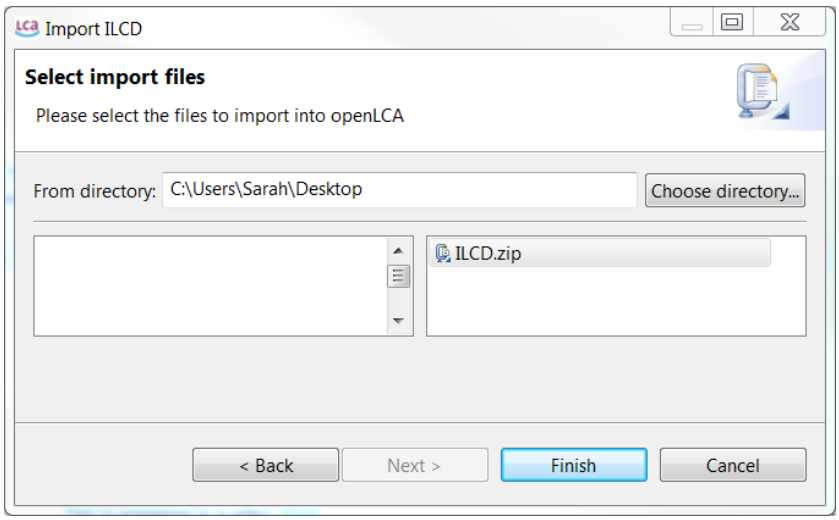


Figure 16: Importing an ILCD dataset, step 3

4.3 Creating a remote database

You can also create a remote database. The name should be the same as in the remote database, and you need to type in the information of the “Host”, “Port” and “User” from the remote database you want to connect (Figure 17).

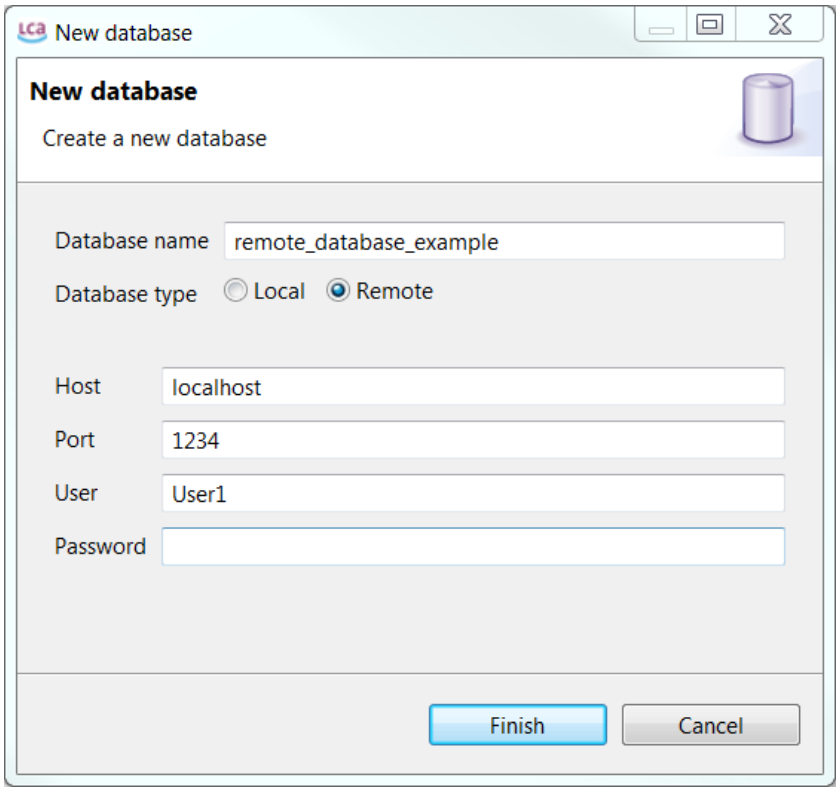


Figure 17: Connecting to a remote database

4.4 Combining databases

It is possible to combine databases into one in openLCA database. An example would be combining the ecoinvent system and unit process databases into one. To do this, import the first database (we recommend importing the largest database first as otherwise the time it takes to compile the databases can be much longer). Then activate the database by double-clicking on it. Then go to "File" --> "Import" and select "Database import" --> "Next", search and select the zolca file of the database you would like to add using the browser. The software will then combine the two databases. Dependent on the size of the databases, this can take a minute or two. Click here to see an instructional video on combining ecoinvent 3.1 databases.

4.5 Database elements

The databases in openLCA contain the following elements:

- Actors: people who have provided data or modified models
- Sources: literature referenced
- Unit groups: groups of units (e.g. units of area include m^2, ft^2, sq.yd, etc.)
- Flow properties: properties of flows (e.g. length, mass, etc.)
- Flows: products and materials
- Processes: production or modification of products and materials
- Impact methods: impact assessment methods imported into openLCA
- Product systems: process networks (necessary to calculate inventory results and impact

assessment)

- Projects: can be created to compare product system variants

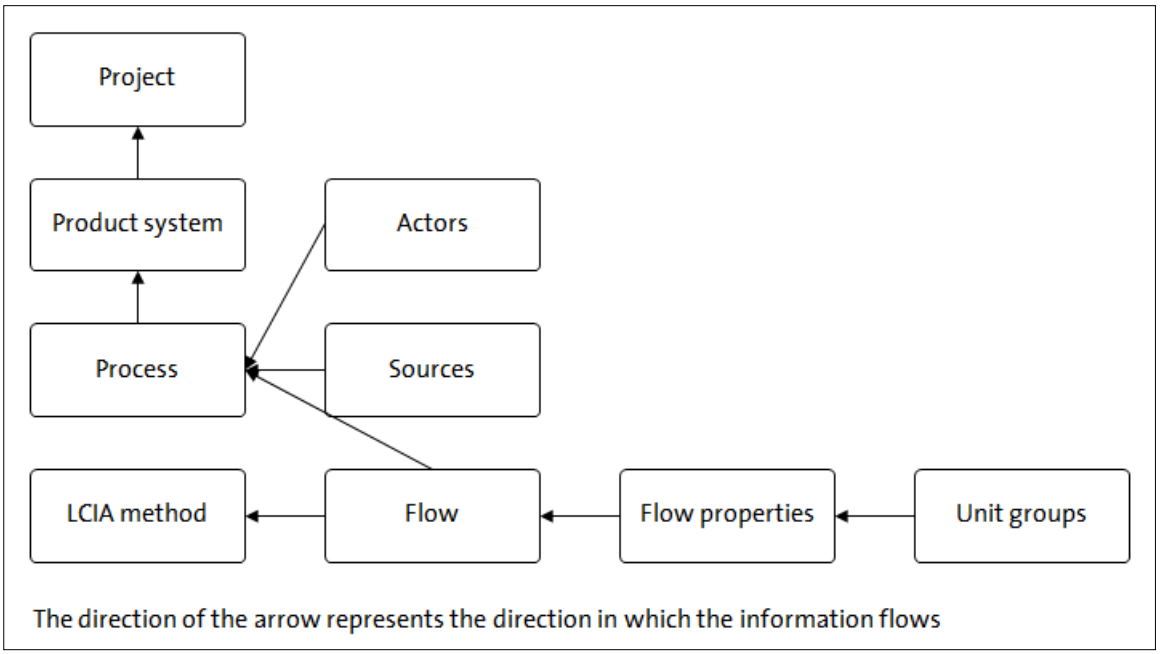


Figure 18: Database element structure and flow of information

4.6 Exporting data

openLCA supports data export in the following formats:

- EcoSpold1 (processes and LCIA methods)
- Ecospold2 (processes)
- ILCD (actors, flow properties, flows, LCIA methods, processes, product systems, sources, unit groups)
- Excel (processes, quick results, analysis results, Monte Carlo simulation results, product systems)
- html File
- ILCD Network Export (entire databases, processes)
- SimaPro CSV (product systems)
- zolca (entire databases)
- "Copy" function for all openLCA tables

How to export these data types will be explained in the following sections.

4.6.1 Exporting data in EcoSpold formats

Processes and impact assessment methods can be exported in EcoSpold1 format. EcoSpold2 files can be created for processes only. To export these file types, activate the database from which you would like to export processes/impact assessment methods. Then click on "File" --> "Export". The export wizard will pop up. Select "EcoSpold2" to export processes as EcoSpold2 files, or "Impact methods" or "Processes" to export these as EcoSpold1 files. In the next window select the directory and processes/LCIA methods to

be exported and click "Finish".

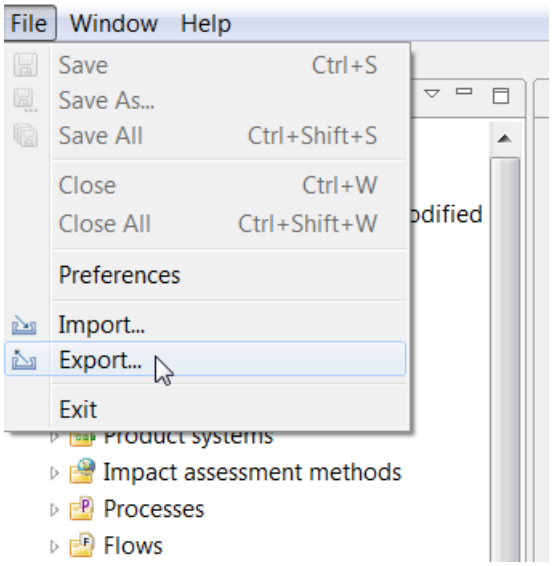


Figure 19: Exporting as EcoSpold1 and EcoSpold2, step 1

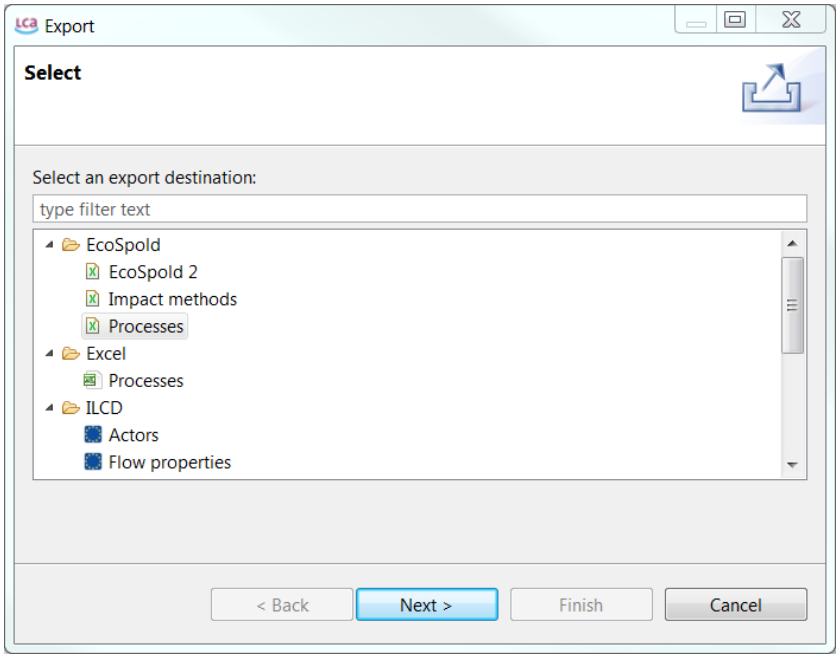


Figure 20: Exporting as EcoSpold1 and EcoSpold2, step 2

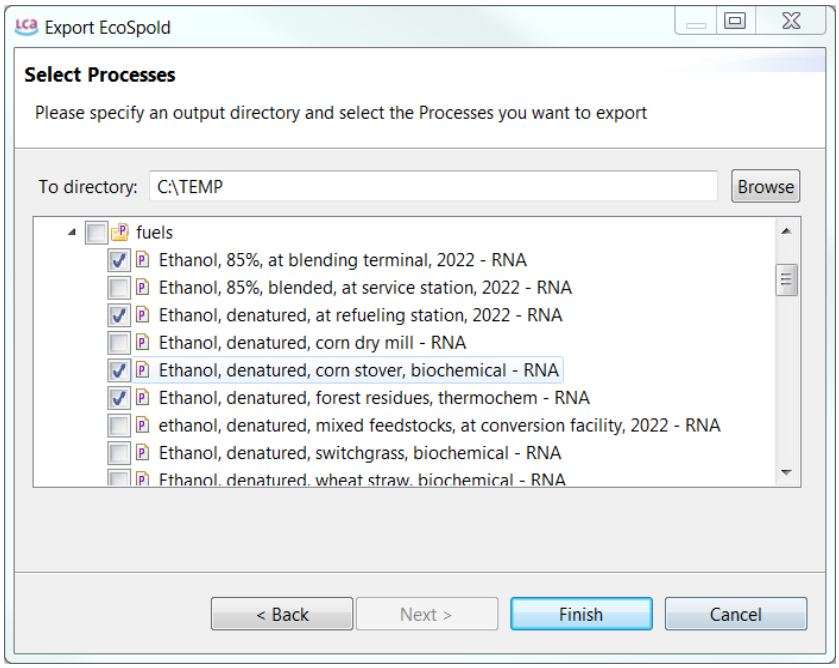


Figure 21: Exporting as EcoSpold1 and EcoSpold2, step 3

4.6.2 Exporting data in Excel format

OpenLCA can export processes, quick results, analysis results, Monte Carlo simulation results, product systems (elementary flows and product flows) and LCIA factors in Excel format. It is also possible to copy any tables from openLCA and paste them elsewhere.

- To export processes as excel files begin by activating the database from which data should be exported. Then select "File" --> "Export" as illustrated in Figure 19. The export wizard will pop up. Select "Processes" in the Excel folder and click "Next". Then select the location where the data should be saved as well as the processes to be saved and click "Finish". Each process will be saved as an individual excel file.
- To export quick results, analysis results, and Monte Carlo simulation results you can either click on the excel export icon in the top left-hand corner or select the "Export to Excel" button under the "General information" tab of the results editor (Figure 22).

Figure 22: Exporting results as excel file

- To export product systems as excel first select the product system in the Navigator to open it up in the Editor. You can then select the excel export icon in the top left-hand corner (Figure 23). The product system excel export wizard will open. The "Methods" section can be filled out or left blank. Select an export directory and click "Finish" (Figure 24). A folder with one excel file for Elementary Flows and one for Product Flows will be saved.

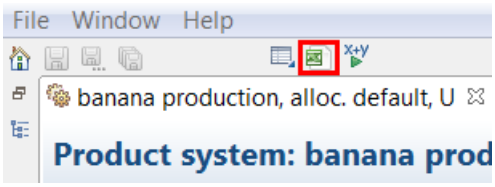


Figure 23: Exporting product system as excel file, step 1

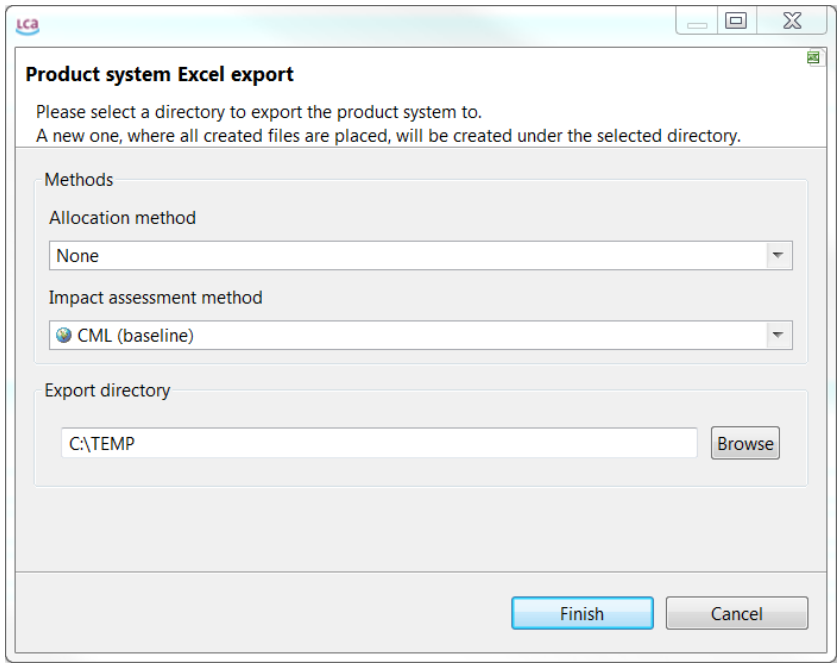


Figure 24: Exporting product system as excel file, step 2

4.6.3 Exporting data in ILCD format

openLCA can export the actors, flow properties, flows, LCIA methods, processes, product systems, sources and Unit groups in ILCD format. To do so, activate the database from which you would like to export. Then click on "File" → "Export". The export wizard will pop up. Select what database elements you would like to export in ILCD format. Then select a directory and the processes, flows, etc. to be exported and select "Finish".

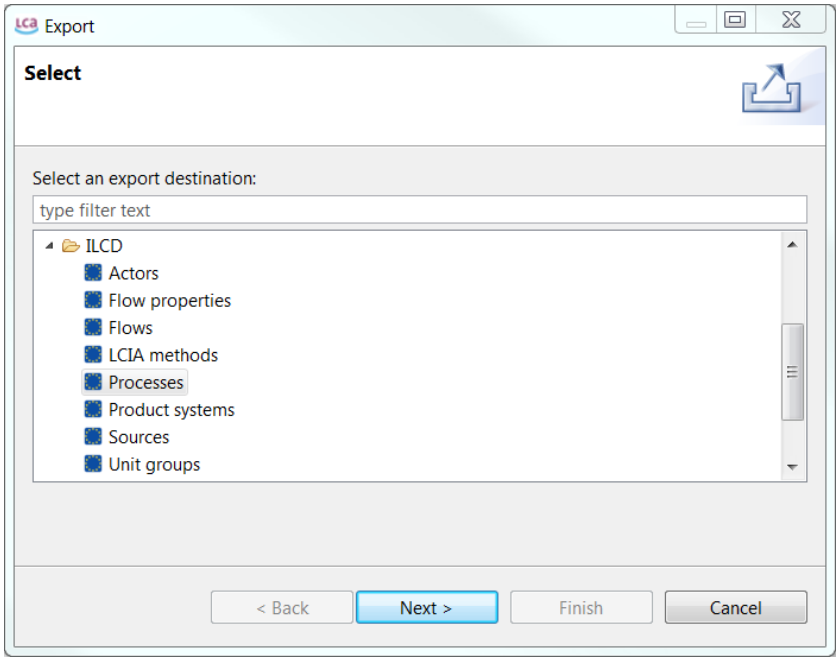


Figure 25: Exporting as ILCD, step 1

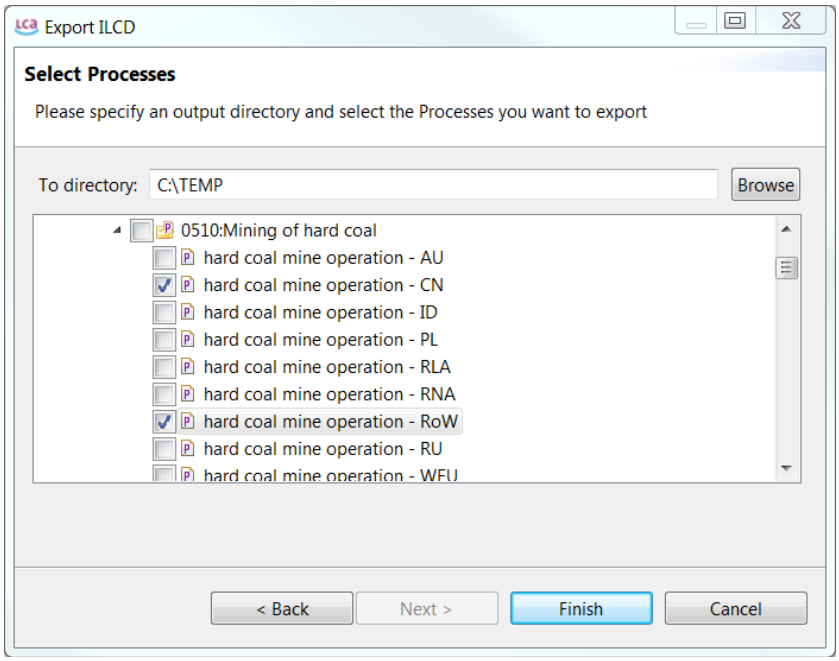


Figure 26: Exporting as ILCD, step 2

4.6.4 Exporting data as html file

openLCA can export Project results as in html format. To do so, calculate a project (see Section 10 to find out how), then select the "Export report" icon when the Report Viewer is open in the Editor (Figure 27). Then simply select a directory and click "Okay".

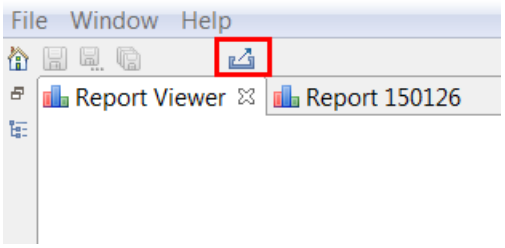


Figure 27: Exporting Project results as html file

4.6.5 Exporting data as CSV-Matrix

openLCA can export the Graph of a product system in CSV-Matrix format. To do so, open the product system you would like to export, then click on the "Matrix export" icon on the top left-hand side (Figure 28). The export wizard will appear. Here you can select the desired decimal and column separators as well as the file destinations for the technology and intervention matrix files (Figure 29). The files will be saved in excel format.

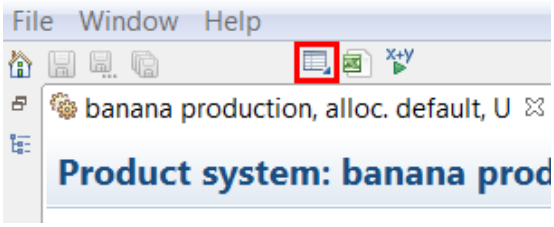


Figure 28: Exporting project results in SimaPro CSV format, step 1

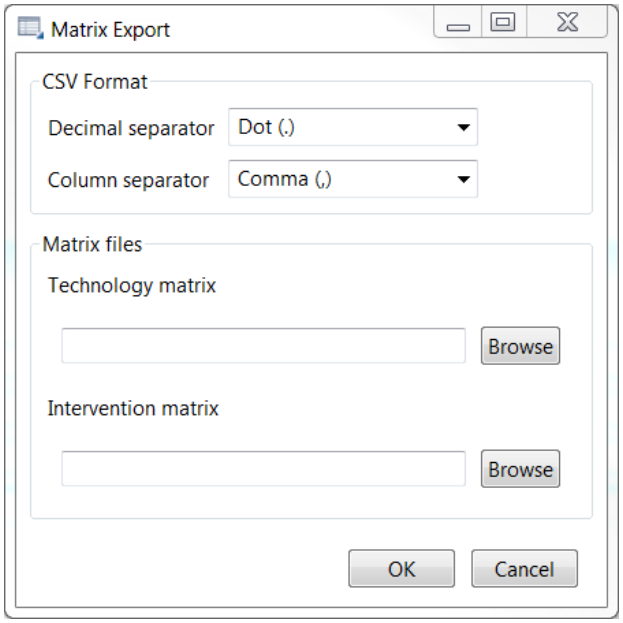
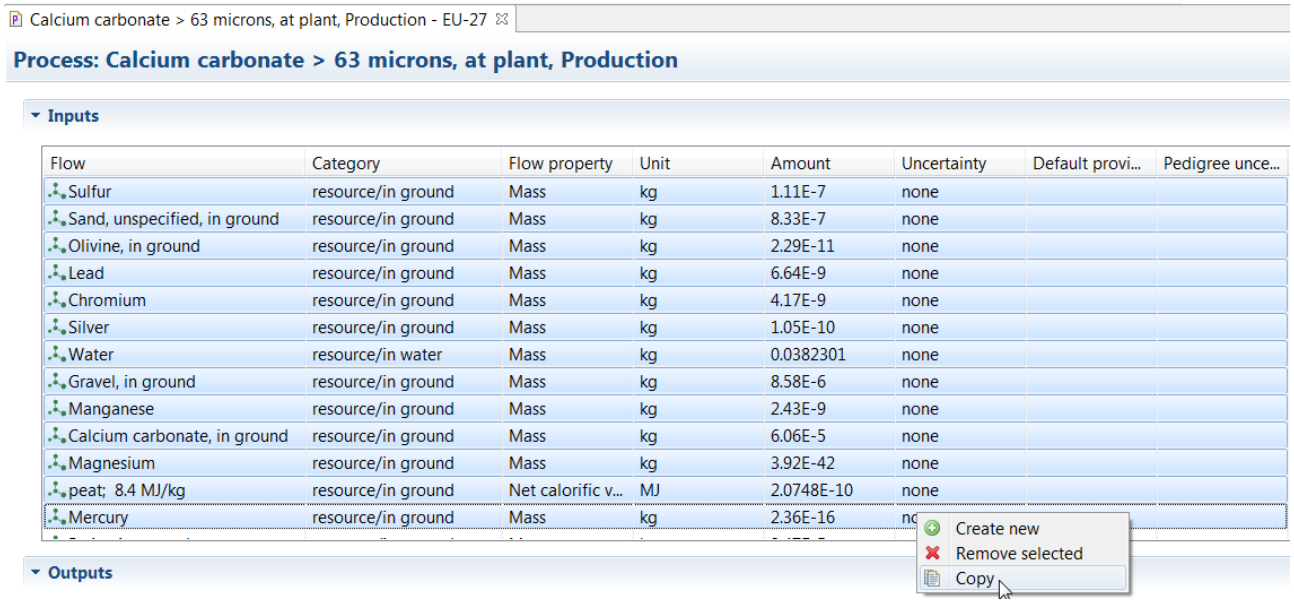


Figure 29: Exporting project results in SimaPro CSV format, step 2

4.6.6 "Copy" function for all openLCA tables

The information presented in all openLCA tables can be copied from the openLCA editor and pasted elsewhere (e.g. in excel, notepad, etc.). To select the columns and rows you would like to copy, select one cell, hold the "Shift" button on your keyboard and then select another cell in the table. All rows and columns in between will be marked. Then you can either right-click and select "Copy" or use the "ctrl/c" function on your keyboard to copy the table. Figure 30 shows an example from a process in the ELCD database (available for free at openLCA Nexus).



Flow	Category	Flow property	Unit	Amount	Uncertainty	Default provi...	Pedigree unce...
Sulfur	resource/in ground	Mass	kg	1.11E-7	none		
Sand, unspecified, in ground	resource/in ground	Mass	kg	8.33E-7	none		
Olivine, in ground	resource/in ground	Mass	kg	2.29E-11	none		
Lead	resource/in ground	Mass	kg	6.64E-9	none		
Chromium	resource/in ground	Mass	kg	4.17E-9	none		
Silver	resource/in ground	Mass	kg	1.05E-10	none		
Water	resource/in water	Mass	kg	0.0382301	none		
Gravel, in ground	resource/in ground	Mass	kg	8.58E-6	none		
Manganese	resource/in ground	Mass	kg	2.43E-9	none		
Calcium carbonate, in ground	resource/in ground	Mass	kg	6.06E-5	none		
Magnesium	resource/in ground	Mass	kg	3.92E-42	none		
peat; 8.4 MJ/kg	resource/in ground	Net calorific v...	MJ	2.0748E-10	none		
Mercury	resource/in ground	Mass	kg	2.36E-16	no		

Figure 30: Copying data from openLCA tables

5 Flows

5.1 Creating a new flow

To create a new flow, right-click on the “Flows” folder and select “New flow”. Name flow and define flow type and reference flow property. Then click „Finish“. A new flow window will open up in the editor (Figure 31).

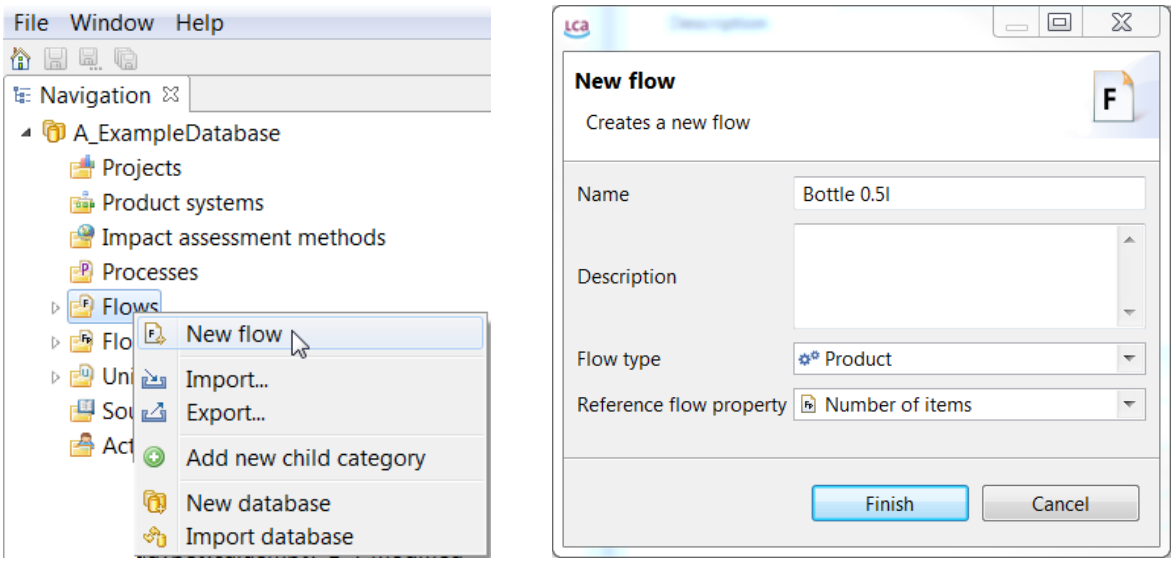


Figure 31: Creating a new flow

5.2 Flow tab contents

5.2.1 General information

In the General information tab you can see and change the name and add a description. It is also possible to add additional information such as a CAS number, formula and location. Under "Used in Processes", you can see which process consume the flow and which produce the flow. If you double-click on a process under "Used in processes", it will open in the editor.

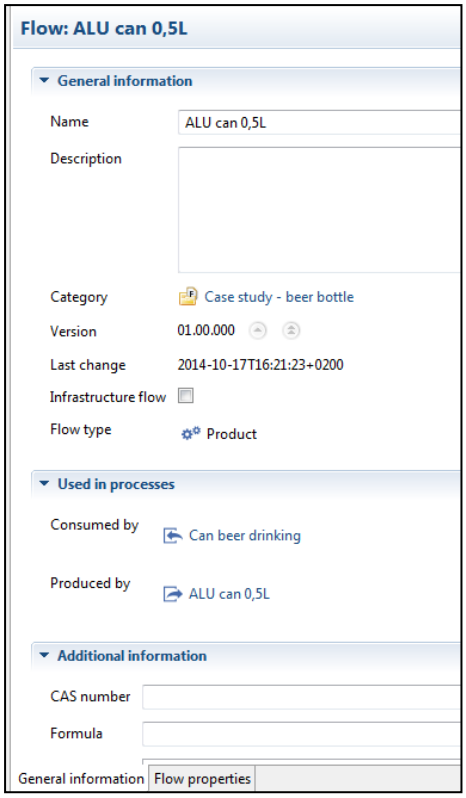


Figure 32: Flow editor - General information tab

5.2.2 Flow properties

Additional flow properties can be added in the “Flow properties” tab. Make sure to type in the correct conversion factor and to select the correct flow property as the reference when multiple flows are listed.

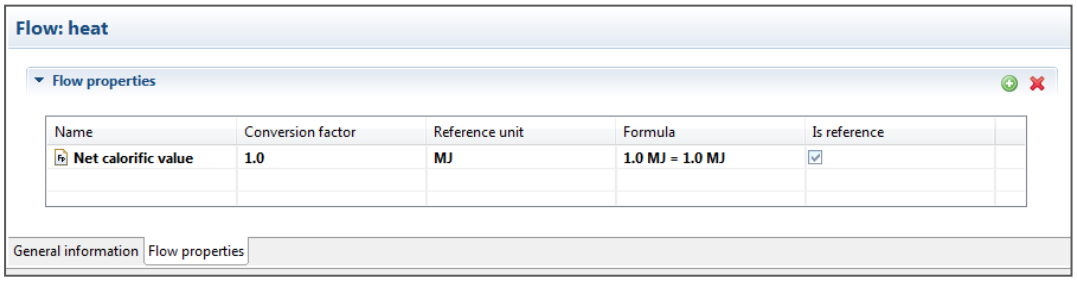


Figure 33: Flow editor - Flow properties tab

6 Processes

6.1 Creating a new process

To create a new process, right-click on the “Processes” folder and select “New process”. Name the process and select a quantitative reference (the reference output of this process). It is also possible to create a new product flow for the process. The product flow will automatically be given the same name as the process. Once "Finish" is clicked, the new process will open up in the editor.

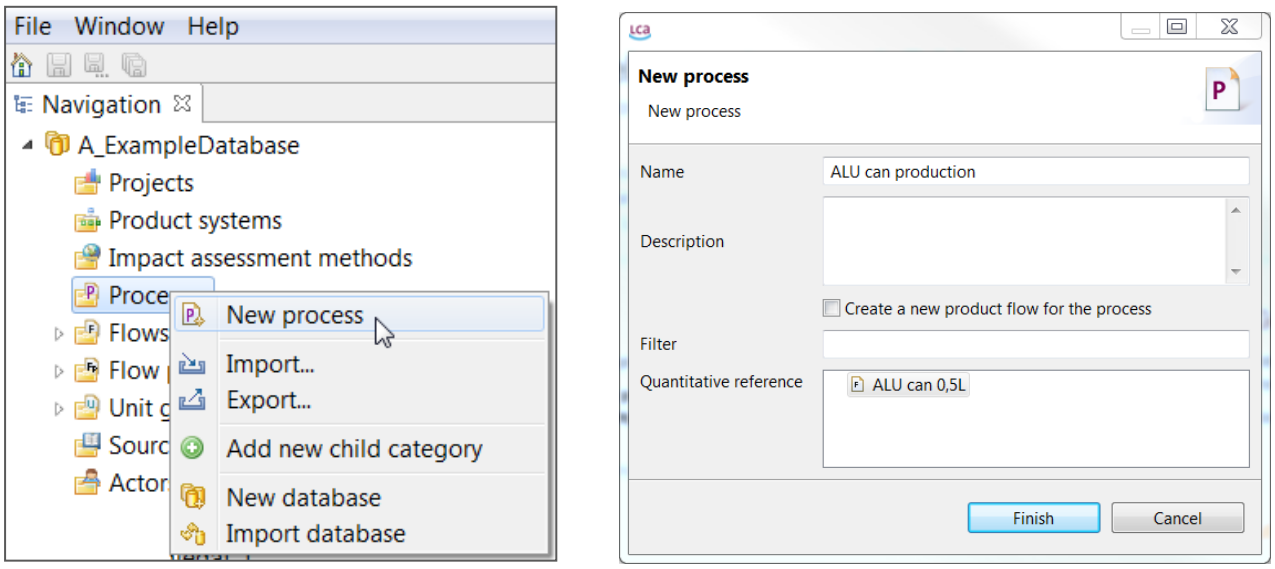


Figure 34: Creating a new process

6.2 Process tab contents

6.2.1 General information

In the General information tab of a process you can change the name, add description, set the quantitative reference, and add geography and technology information. It is also possible to create a product system from here (to find out how, Section 8.1).

6.2.2 Inputs/Outputs

Here, product, elementary and waste flows are listed as inputs/outputs. Their respective categories, flow properties, units and amounts are also contained in these tables. Flow properties can be changed (assuming the flow has more than one flow property). It is also possible to change units by clicking on the amount cell and selecting a new unit from the list.

Amounts can be typed in as values, formulas and/or parameters. Complex formulas require a certain format (e.g. Tan(a), trunc(c), etc.). Use the formula interpreter to find errors (available under "Window" → "Formula interpreter"). When a formula and/or parameter is typed in the "Amount" field, the software will calculate the value for the amount automatically. See the calculated value, click on this button: 

. To see the original formula/parameters, click on the button again. Under "Default provider" you can select a specific flow provider (when more than one provider for a specific product flow exists).

6.2.3 Administrative information

This section is quite self-explanatory. Entries to administrative information have no affect on calculations.

6.2.4 Modelling and validation

Here it is possible to set the process type (as unit or system process) and add information about the dataset. Add reviewers by clicking the "Add actors" icon in the section "Process evaluation and validation". If the actor you would like to add is not included under "Actors", you can add an actor by right-clicking on the "Actor" folder in the Navigation and selecting "New actor". To add a source, click on the green "+" icon in the section "Sources". Once again, if the source you require is not listed, you can add a new one by right-clicking on the "Sources" folder in the Navigation and selecting "New source".

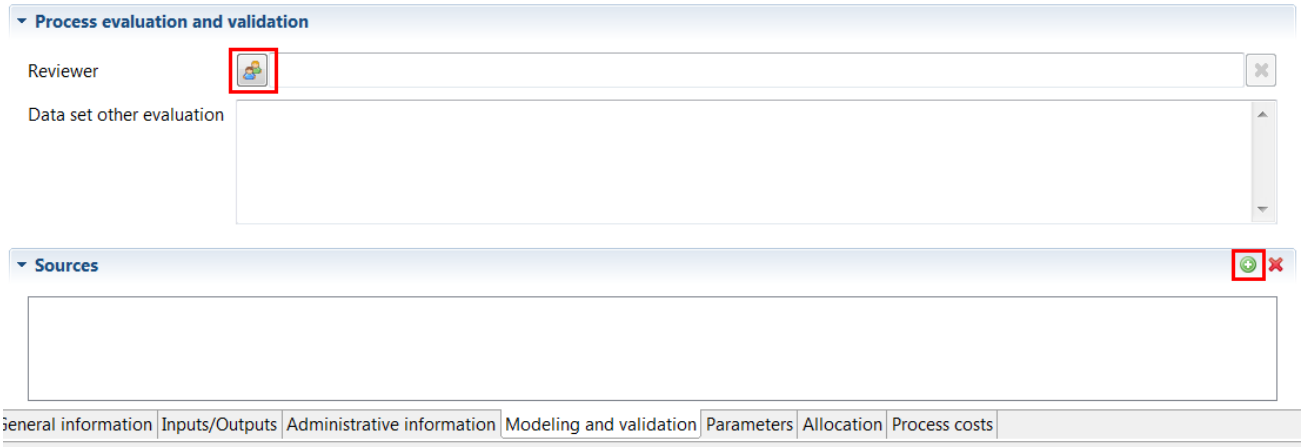


Figure 35: Adding a reviewer or source to processes

6.2.5 Parameters

Parameters can be used on the process, Impact assessment method, product system, project and

database levels. Parameters can be used instead of concrete values for inputs/outputs. They can be defined as simple values, formulas or complex functions. Parameters can overwrite each other (e.g. the value set for a parameter in a process can be overwritten on the product system/project levels).

There are some rules when it comes to parameters. Parameter names cannot contain special characters or more than 255 characters. Parameter formulas can contain single values, simple equations, or complex functions including logical expressions. Parameter formulas do not contain units, (so please add them in the comment field), and cannot have more than 255 characters. Theoretically, the amount of parameters is unlimited. When you assign an amount to a parameter, use point (.) instead of comma (,) for the decimal numbers.

"Global" parameters can be found and are valid on all levels. "Input" parameters are parameters that are only valid for the process/LCIA method/Product system in which they are saved. "Dependent" parameters are parameters that include input or global parameters in their formula. See Figure 36 for an example.

New global, input and dependent parameters can be created within a process or impact assessment method. These are then also available in product systems and projects (note: it is not possible to create a new parameter on the product system or project levels). To create a global parameter you can either select "File" → "Preferences" → "Global parameters" and add new parameters using the green "+" button, or select the global parameters "Edit" button in the "Parameters" tab of a process or impact assessment method (see Figure 36).

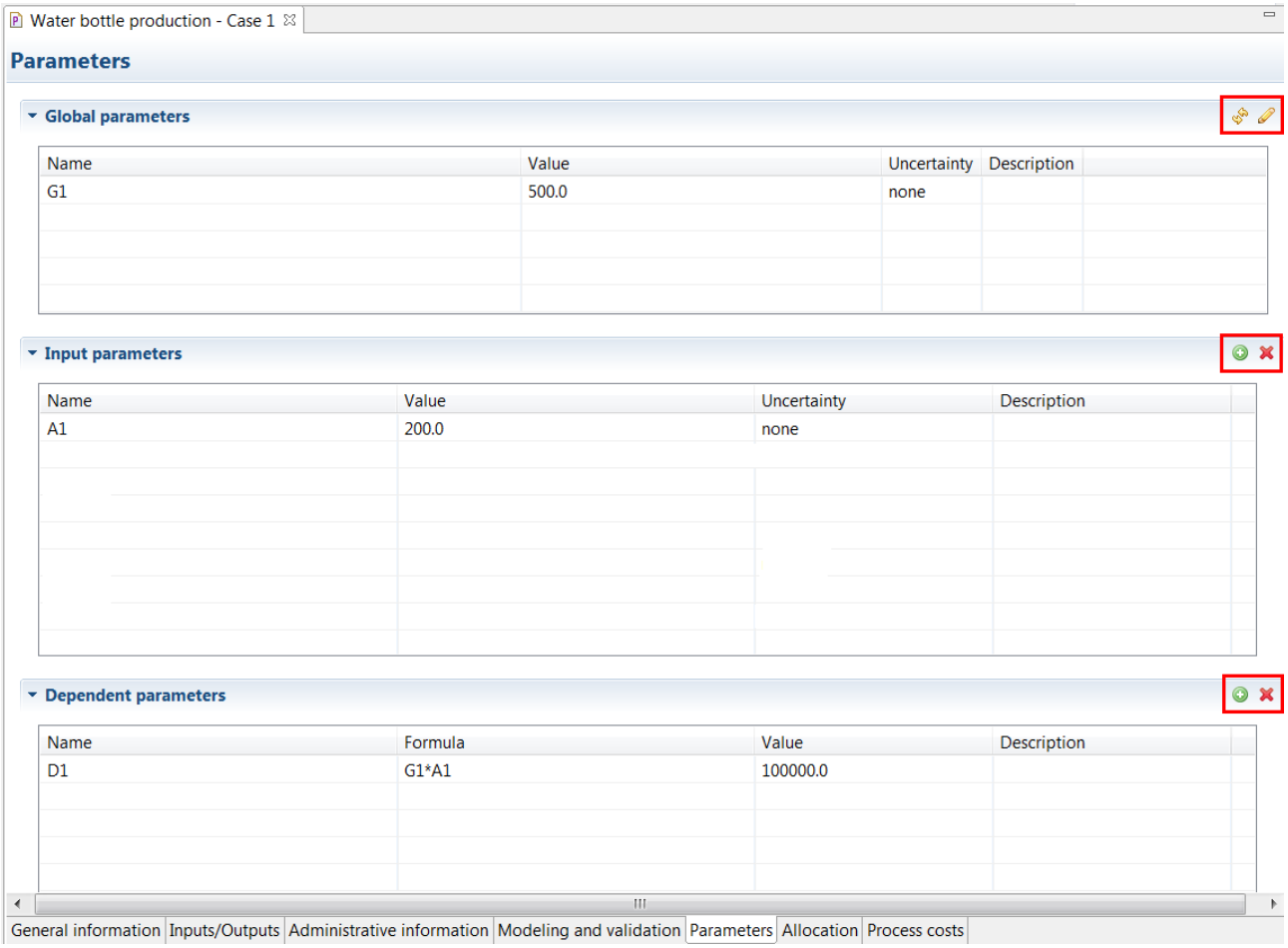


Figure 36: Global, Input and Dependent parameters

6.2.6 Allocation

Usually, life cycle assessment requires single-output processes, but this is not always the case. Multi-output processes (e.g. co-generation of heat and power, simultaneous milk, leather and meat production, etc.), however, occur frequently. These situations can be dealt with using two different strategies, namely through allocation (in which elementary flows and products from multi-output processes are mathematically divided into multiple processes) or system expansion (to avoid allocation).

There are 3 allocation methods in openLCA:

- physical allocation
- causal allocation
- economic allocation

The values (allocation factors) for physical, causal and economic allocation can be viewed/altered in the "Allocation" tab. In order for allocation to work, the main product and the co-products of the multi-output process need to have the same flow property. Select the "Calculate default values" button and the software will automatically calculate the values for all three allocation types. For physical allocation,

the default (reference) flow property is used to calculate they physical ratio between the main product and the co-product on the bases of their amounts, e.g. in units of mass or energy. For economic allocation, the allocation factors are based on the economic value of product flows. Thus, in order to apply economic allocation you first need to add an economic flow property to each product flow. Causal allocation can be applied by manually inserting the desired allocation factors in the causal allocation section.

Figure 37 illustrates allocation for co-generation of heat and electricity. The physical allocation factors are automatically calculated on the basis of the ratio between the product outputs of the process as expressed in the reference flow property (e.g. MJ). For this example, the output flows for electricity and heat are 2MJ and 1MJ, respectively, thus resulting in the physical allocation factors 0.66 and 0.33. The market values for the output product flows were set at 0.79€/MJ and 0.36€/MJ for electricity and heat, respectively (see Figure 38). This results in the economic allocation factors you can see below. The causal allocation factors (0.6 and 04) were inserted manually on the basis of assumptions/prior [redacted]entific research on the relative impacts arising from each output.

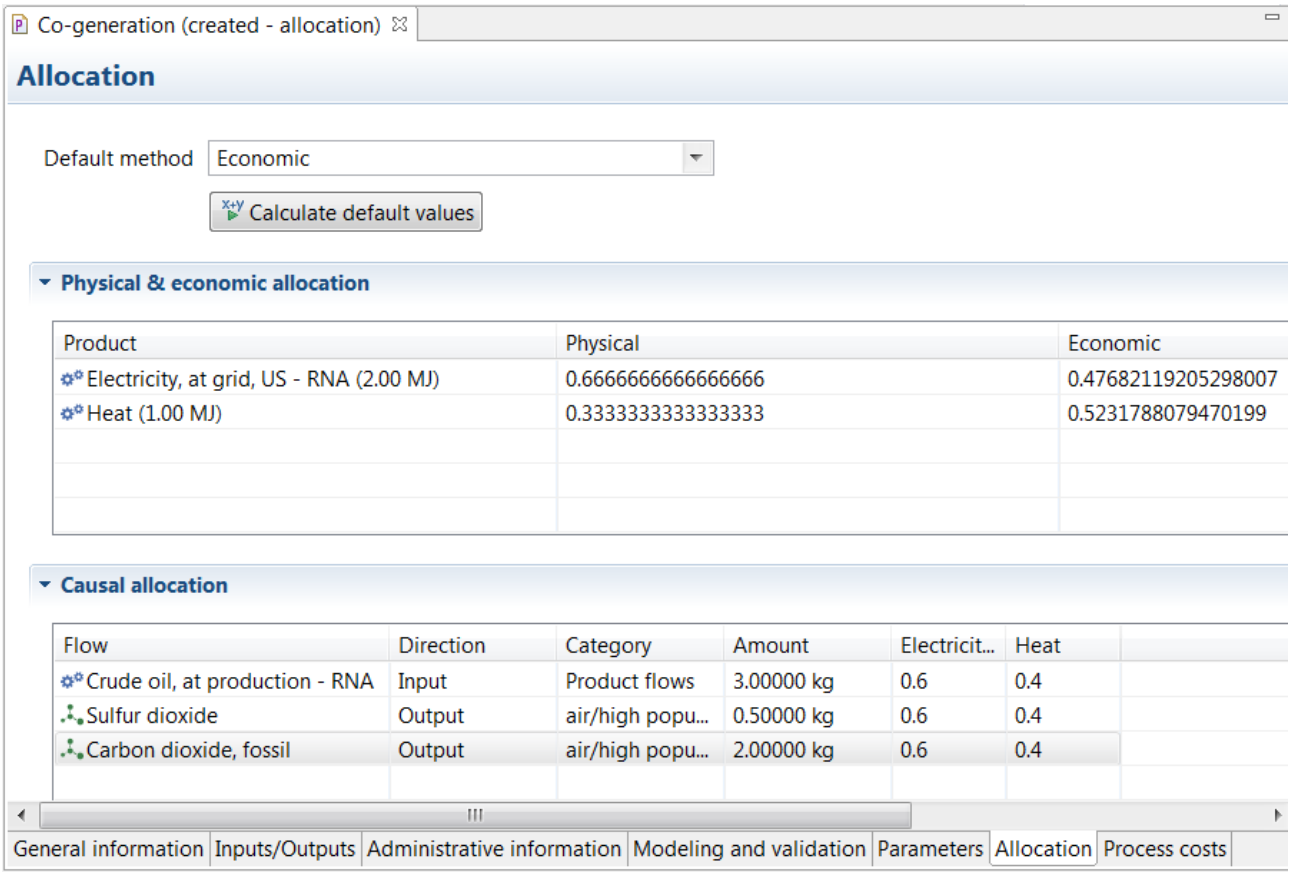


Figure 37: Physical, causal and economic allocation

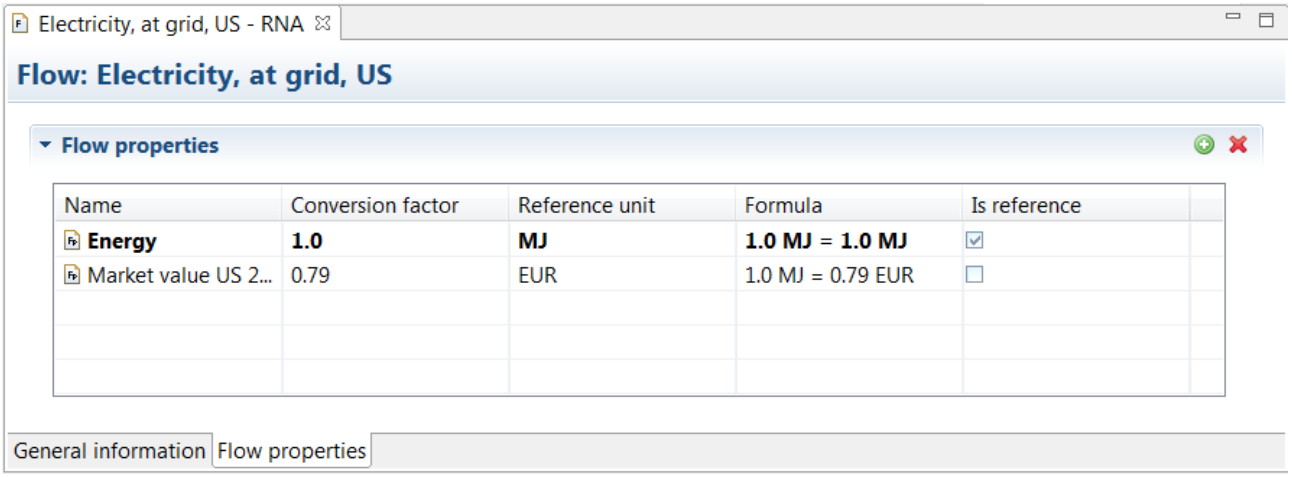


Figure 38: Flow market value

7 LCIA METHODS

The databases in openLCA Nexus do not contain LCIA methods (termed "impact assessment methods" in the software). LCIA methods need to imported/created manually in each database in openLCA in order to carry out life cycle impact assessment.

7.1 Importing LCIA methods into openLCA

A LCIA method pack openLCA is available at www.openlca.org/downloads. This comprehensive package of environmental impact assessment methods is formatted for use with all of the databases available at openLCA Nexus, including, for example, ecoinvent 3, GaBi and ELCD. This pack includes normalisation and weighting as far as this is foreseen by the method. A pack containing a social LCIA method for use with the Social Hotspots Database also available at www.openlca.org/downloads. Ecoinvent LCIA methods are also available for openLCA. You can download these from openLCA Nexus (https://nexus.openlca.org/database/ecoinvent). A LCIA method developed especially for Ökobaudat is contained in the database file when downloaded from openLCA Nexus for openLCA.

Once you have downloaded one or more of these method packs to your computer, you can then import them into an openLCA database. To do so, begin by activating the database in which the method pack should be imported. Then either right-click in the navigation window and select "Import" or go to "File" --> "Import". Then select "Database import" from the "Other" folder of the import wizard. In the next window select "From exported zolca file", browse for the file and finally select "Finish". The import will then begin automatically.

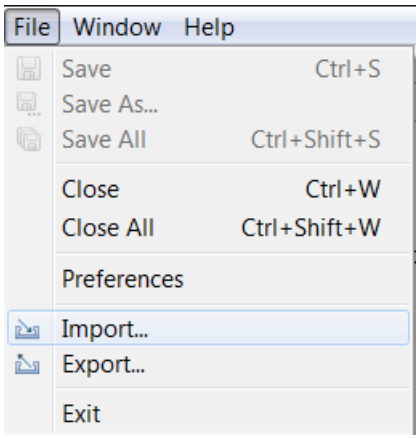


Figure 39: Importing LCIA methods, step 1

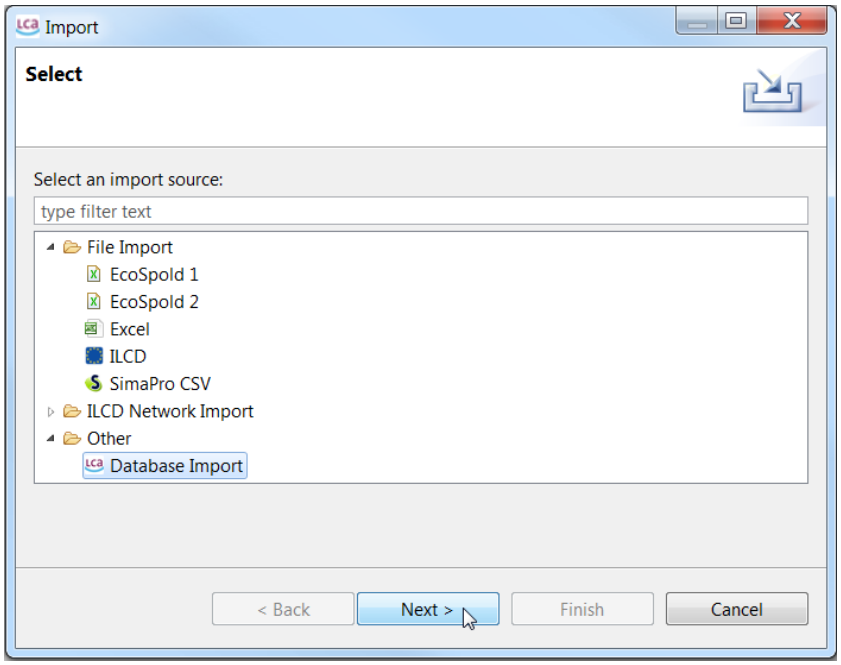


Figure 40: Importing LCIA methods, step 2

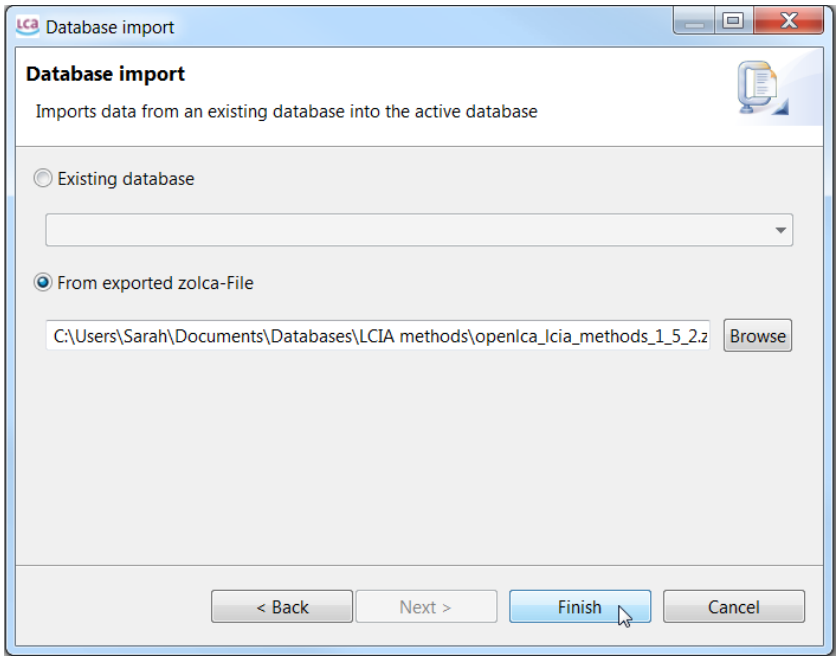


Figure 41: Importing LCIA methods, step 3

This import may take a few minutes. When it is finished, the LCIA methods will be available in the database, as shown in Figure 42.

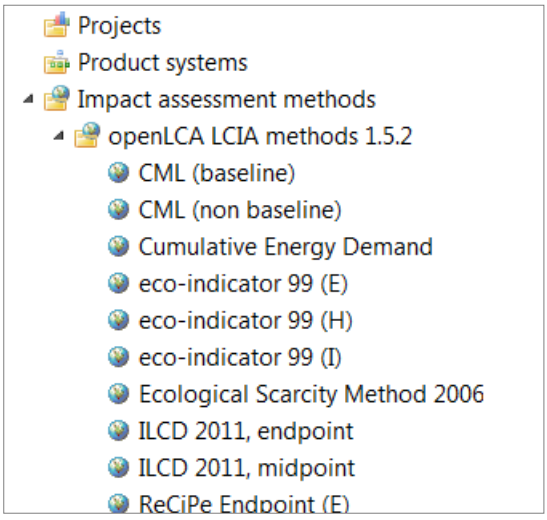


Figure 42: LCIA methods in openLCA

7.2 Creating a new impact assessment method

To create a new life cycle impact assessment method, right-click on the “Impact assessment methods” folder and select “New LCIA method”. Name the new method and add a description (optional). Once "Finish" is clicked, the new impact assessment method will open up in the editor. To see how to add impact categories, characterization factors, etc, see the next section.

7.3 Impact methods tab contents

7.3.1 General information

Here you can change the name and description of the method as well as add/remove impact categories. To add a new impact category, click on the green "+" button on the right-hand side. Then simply name the category and type in a reference unit and description (optional). Figure 43 shows an example of the General information tab for the CML (baseline) LCIA method from the openLCA method pack.

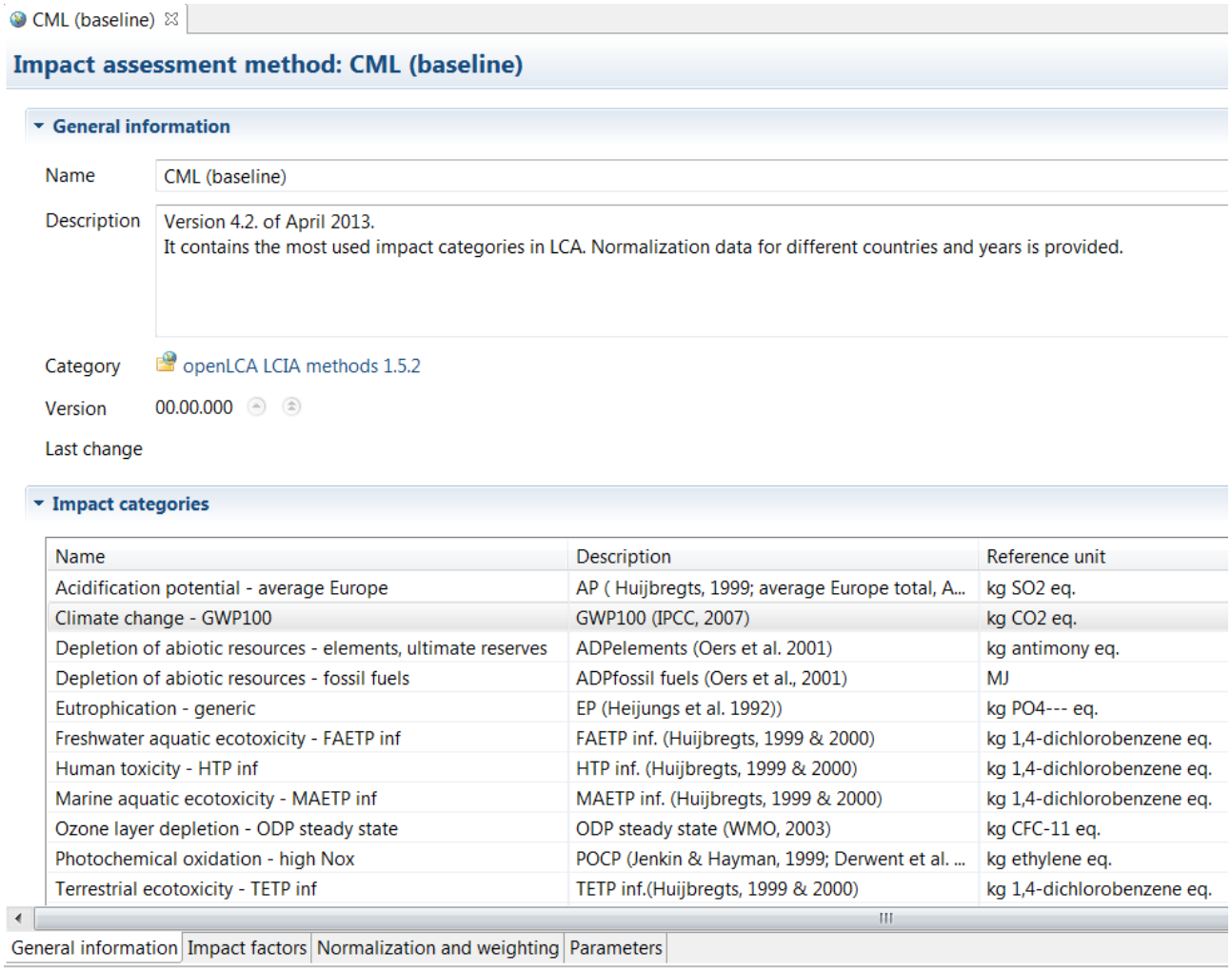


Figure 43: LCIA methods - General information tab

7.3.2 Impact factors

Flows as well as their corresponding characterization factors, categories, flow properties, units and uncertainty data can be added/removed/edited in this tab. Begin by selecting the desired impact category. Then add or remove flows using the "+" and "X" buttons on the top right-hand corner of the editor. Then type in the characterization factor for each flow as well as the uncertainty distribution, if applicable.

7.3.3 Normalization/Weighting

To add normalization and weighting factors to the impact categories of a LCIA method, begin in the "Normalization and weighting" tab by clicking on the green "+" tab to add a new set. The impact categories saved in the method will automatically appear in the window on the right, where you can then manually type in normalization and weighting factors.

7.3.4 Parameters

Parameters can be used in the same way for LCIA methods as for processes, as described in Section 6.2.5.

8 Product systems

As in ISO 14040, the life cycle model of a product is called a product system. There are different ways to create, edit and complete product systems, depending on the database and user preferences, which will be explained in the following section.

8.1 Creating a new product system

There are two ways to create a new product system. For option one, begin by right-clicking on the "Product systems" folder and select "New product system". The second option is to create a product system directly from a process. To do this, go to the "General information" tab of the process and select the button "Create product system". The next steps are then the same for both cases. Namely, a pop-up window will appear in which you can name the product system, add a description (optional) and select a reference process. A reference process is the process at the very end of the chain. If you create a product system directly from a process, that process will automatically be selected as the reference process. Otherwise, by entering the text into the "Filter" field, you can narrow down the selection which helps to identify the desired process.

To automatically have all processes connected to the reference process, check off "Add connected processes". Checking "add connected processes" in the product system wizard will make openLCA connect those processes that have the same products, for the same locations, and where the units of the flows can be converted. For many databases, such as the ecoinvent database, these criteria clearly identify the delivering process. It is also possible to manually define the delivering processes which should be connected before creating the product system. To do this, select a "Default provider" for input flows in the "Input/Output" tab of the process. If you prefer connections to system processes, check off "Connect with system processes if possible". Otherwise, the software will select unit processes over system processes. If these two boxes are not checked off, the product system will not contain any connections to upstream processes (this can be done manually later, see Section 8.2.3). Then select "Finish" and the new product system will open in the Editor.

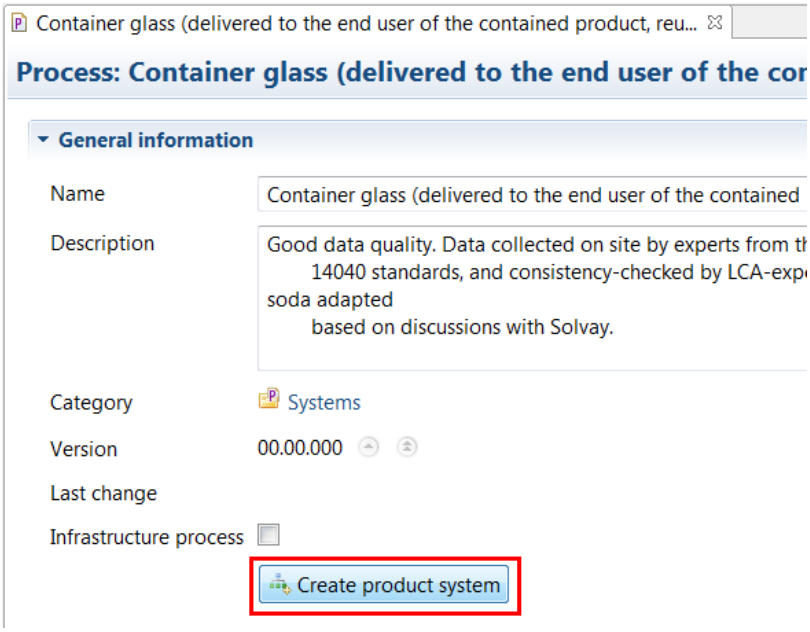


Figure 44: Creating a product system, step 1

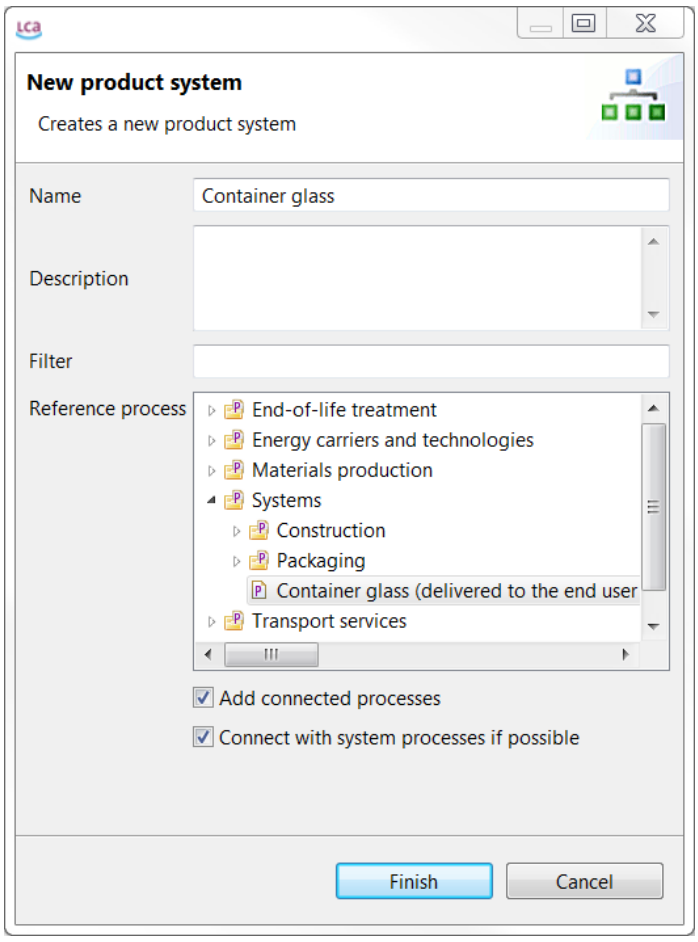


Figure 45: Creating a product system, step 2

After creating a product system, it is possible to add and delete connections using the "Model graph".

This will be described in Section 8.2.3.

8.2 Product system tabs contents

8.2.1 General information

Here you can change the name of the product system as well as add a description (optional). In the "Reference" section you can see the reference process and make changes to the reference product, flow property, unit and the target amount. The target amount should be selected in accordance with your functional unit. It is also possible to calculate a product system from the general information tab. For more information, please see Section 8.3.

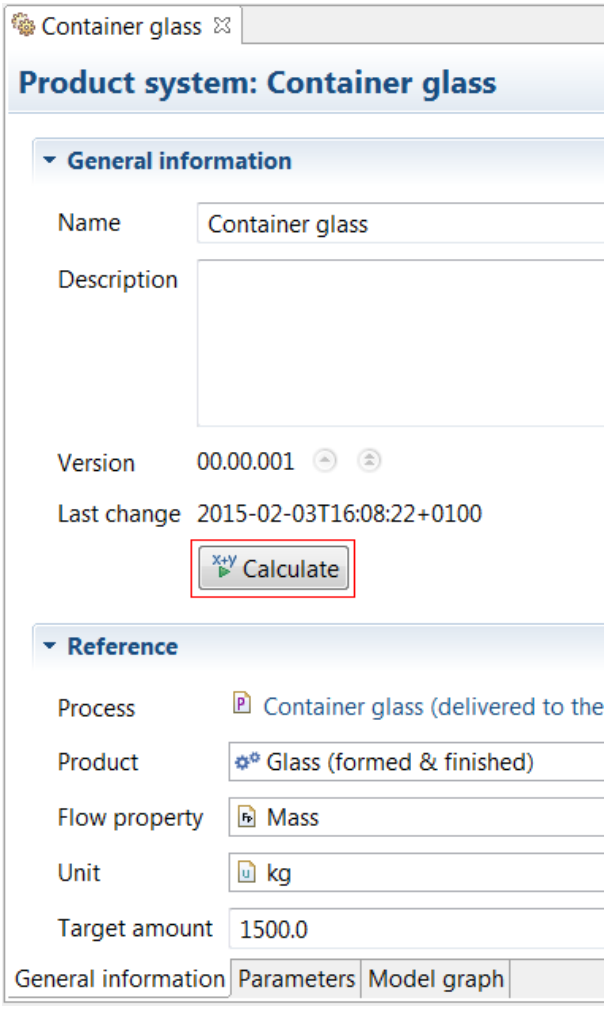


Figure 46: Product system - General information tab

8.2.2 Parameters

In the product system level, it is possible to change the amounts of parameters defined in the processes included in that particular product system. To do so, add the parameter for which you would like to change the amount by selecting the green "+" button in the top right-hand corner of the Editor and selecting one. To select multiple parameters at once use your keyboard's "Shift" button. The amounts

saved in a product system will override those saved in a process. However, the values saved in the process will not change. It is not possible to create new parameters on the product system level.

8.2.3 Model graph

The model graph in the product system shows the connected processes. These connections can be edited (added/deleted) and processes can be entirely deleted from the product system if they have no connections in the life cycle any more. Only connected processes will contribute to the product system's calculation. To find out more, see the next sections on making alterations to the product system within the model graph and on calculating product systems.

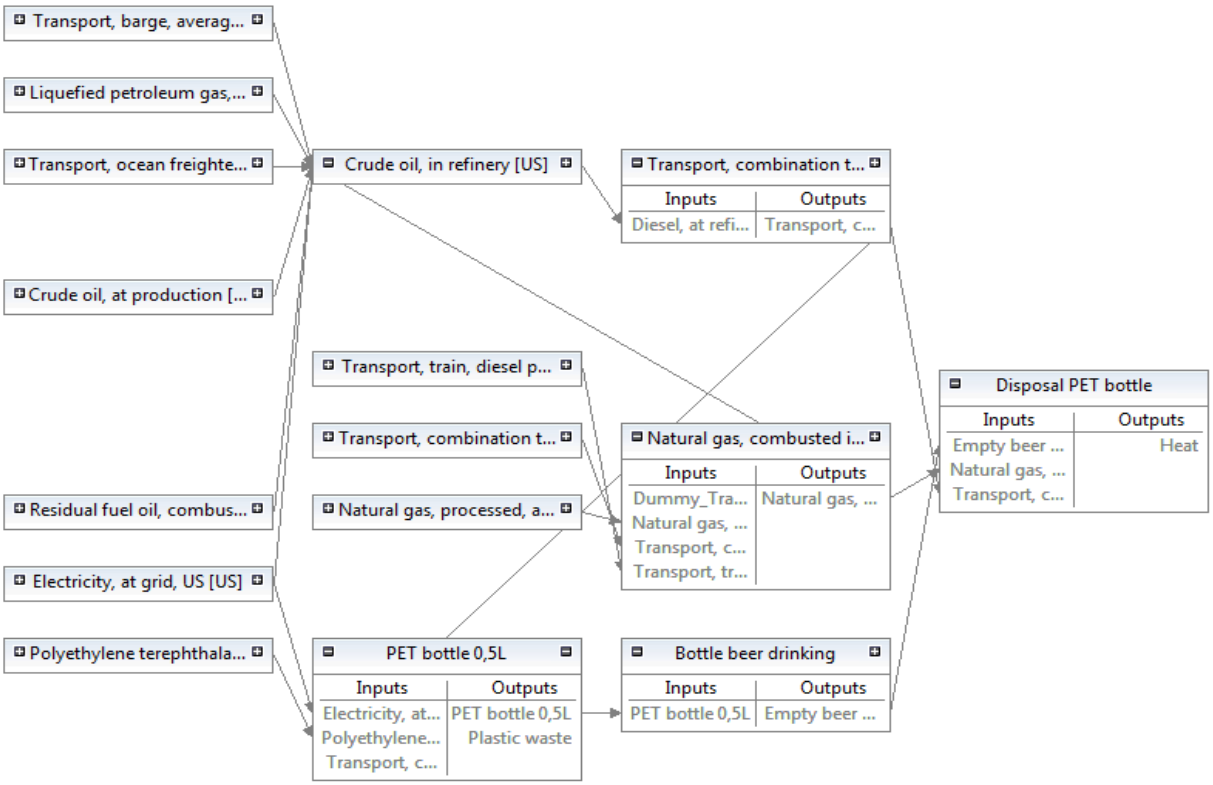


Figure 47: Product system model graph - example

By right-clicking on the background of the model graph, the following options will appear:

- Save as image (save image of model graph as .png file)
- Expand all (expand model graph to show all connected processes)
- Collapse all (minimize connected processes to show only first and second tier)
- Maximize all (expand processes' view to show inputs/outputs)
- Minimize all (show only process names, no inputs/outputs)
- Layout (choose between "Layout as tree", "Layout as minimal tree" to organize the model graph; select "Route" to have the model graph displayed with connections made of right angles)
- Show outline (the "Outline" lists all processes in the product system alphabetically. To find a

process in the model, right-click on the flow in the Outline and select "Show" and it will appear in the model graph)

- Open miniature view (useful for navigating your way around complex model graphs by giving a miniature overview of the model graph. The blue area represents the current view. See Figure 48)

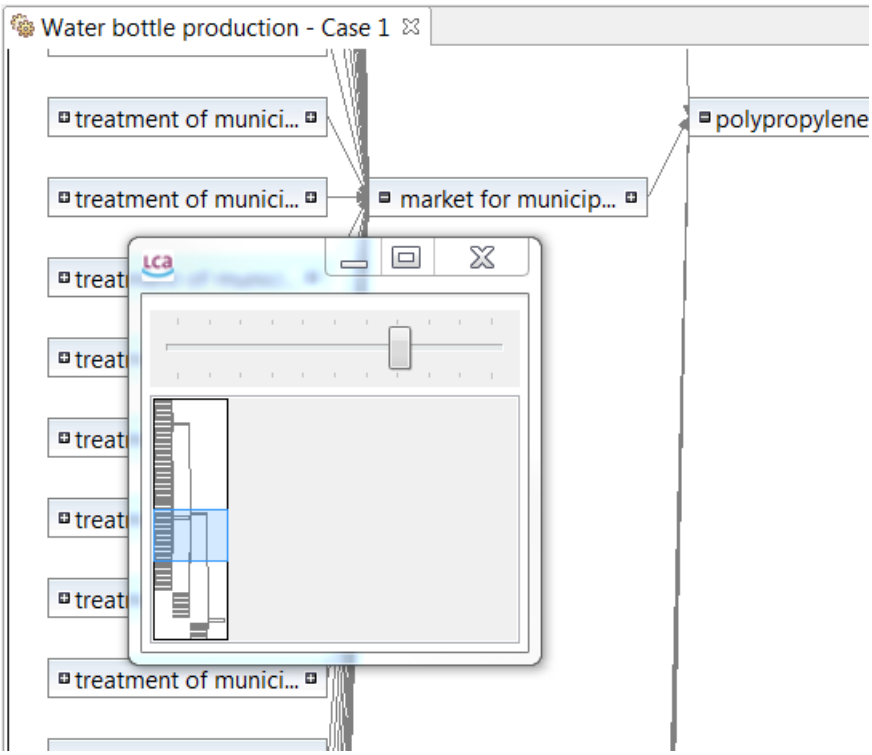


Figure 48: Model graph - miniature view

As an alternative to the automatic connection of processes, you can also manually connect processes in the model graph of a product system. By right-clicking on the processes, under "Build supply chain" you can then select whether to build the entire supply chain for the process, or just the next tier.

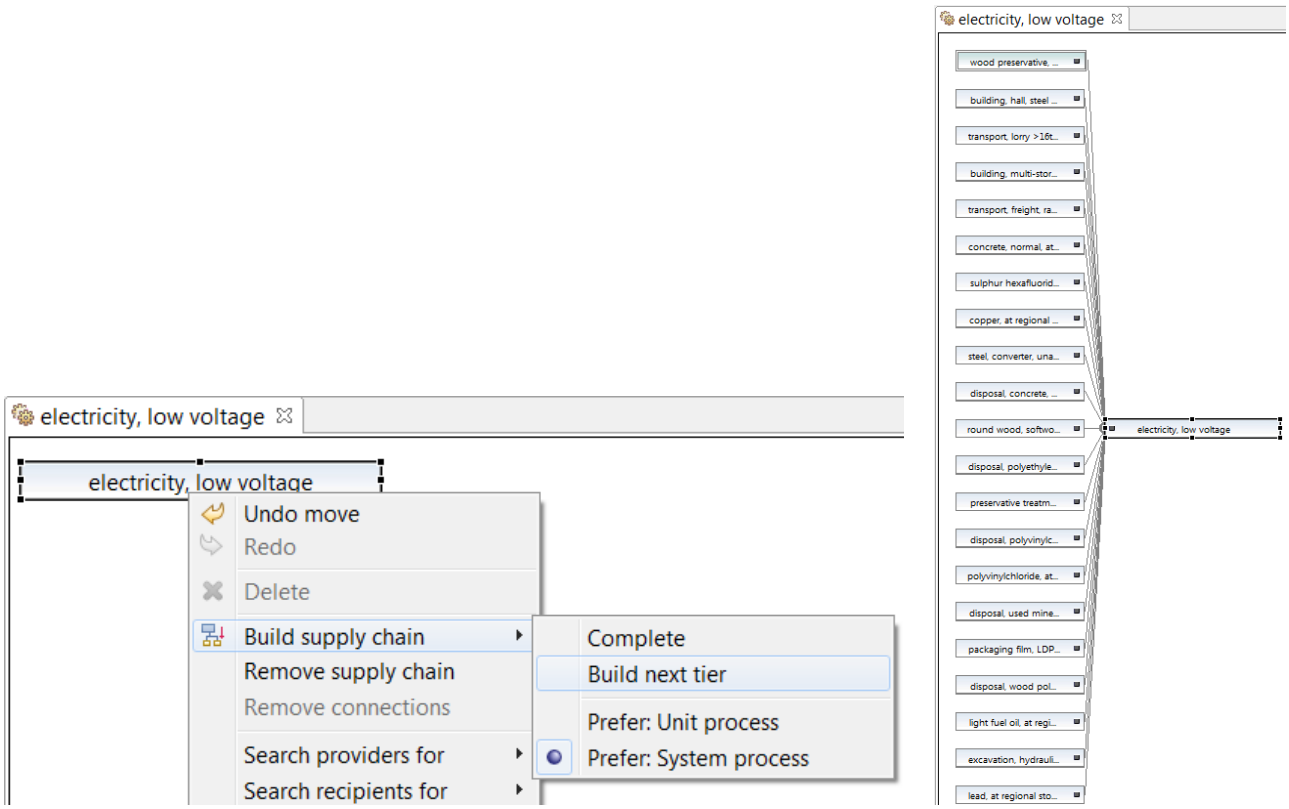


Figure 49: Model graph - build next tier

Selecting "Search providers for" allows you to select the providers for each individual product of the process. To do so, right-click on a process, select "Search providers for" and then select the respective product. A pop-up window will appear with a list of all possible providers for that product. Select in the table which provider you would like to add to the model graph and check off "Connect" to automatically connect the process to the product. Likewise, it is possible to search for recipients for specific outputs.

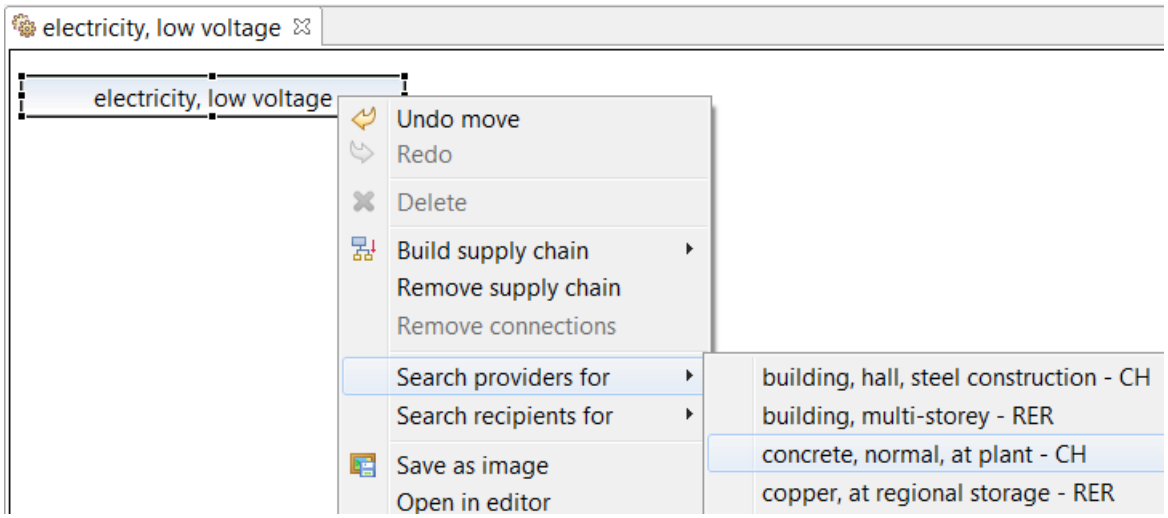


Figure 50: Model graph - search providers for, step 1

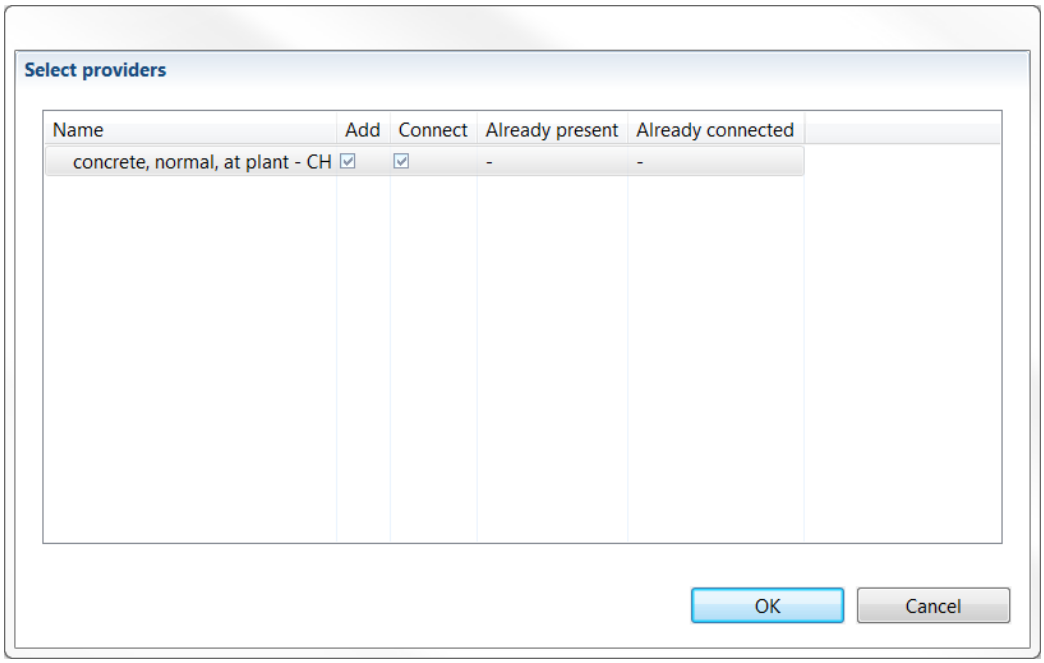


Figure 51: Model graph - search providers for, step 2

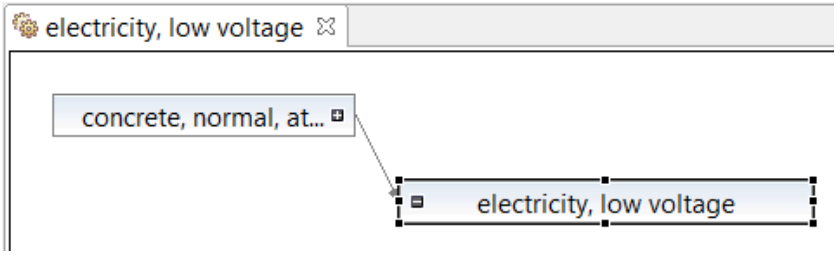


Figure 52: Model graph- search providers for, connected process

Another way to connect inputs/outputs to their respective providers/recipients is to 'draw' the connection manually in the model graph. Click on a not-connected input/output and guide the mouse to the respective provider/recipient. The ⊘ next to the mouse indicates that no valid provider/recipient has been selected:

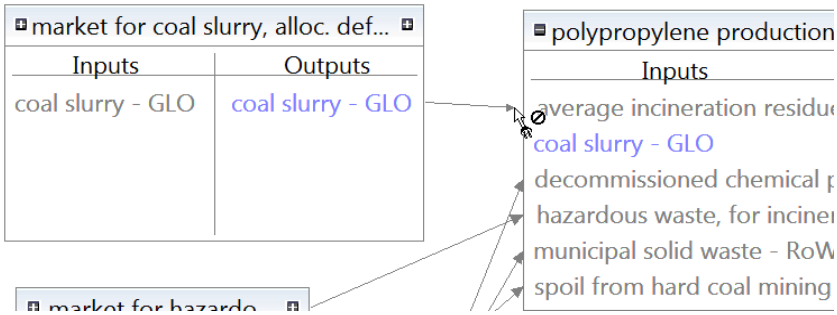


Figure 53: Model graph - drawing connections, step 1

Release the mouse when over valid provider/recipient and the connection will be made:

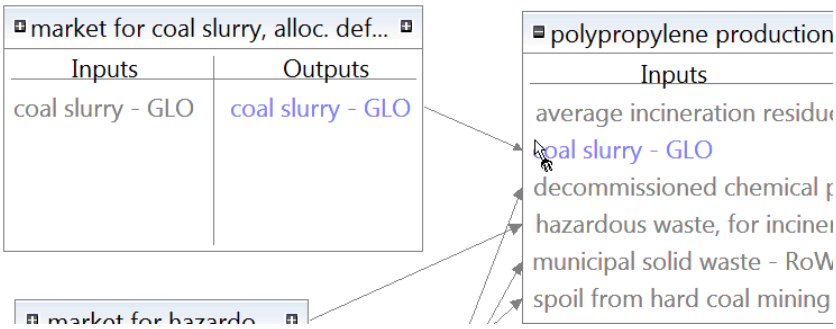


Figure 54: Model graph - drawing connections, step 2

It is also possible to delete connections in the graph. To do so, simply right-click on the connection arrow and select "Delete":

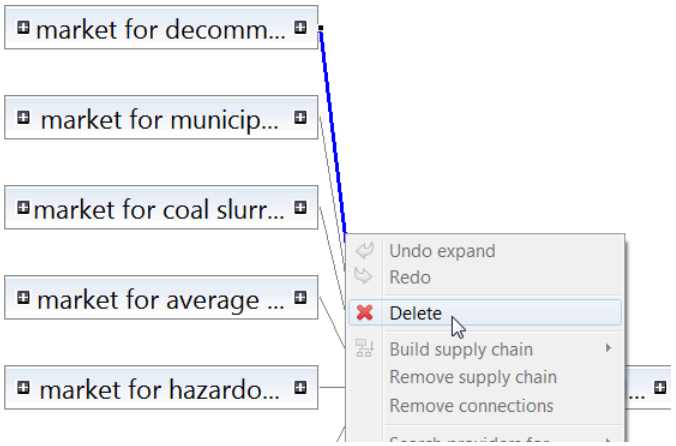


Figure 55: Model graph - deleting connections

Once a connection has been deleted, the upstream process will still be shown in the model graph; however, as it is not connected, it will not contribute to the calculation. Delete an unconnected process by right-clicking on it and selecting "Delete".

8.3 Calculating a product system

When you have a product system open in the Editor, there are two ways to initiate calculation. Either select the "Calculate" button from the General information tab of the product system or the "Calculate results" icon in the top left-hand corner:

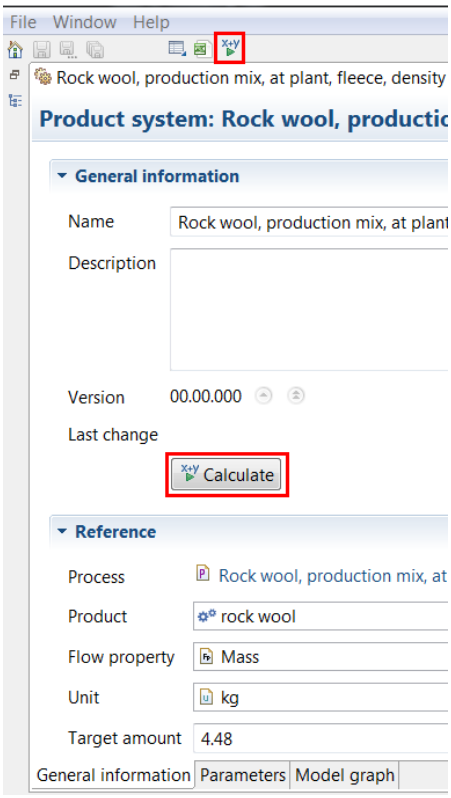


Figure 56: Calculating a product system, step 1

You can then select the calculation properties in the wizard. For allocation, "None" is the default setting. Otherwise, you can choose between the options "Causal", "Economic", "Physical" or "As defined in processes". Then, select the desired impact assessment method from the list of methods available in your activated database (if no methods are listed you need to first import one or more methods into the database or create a new method). If applicable, select a normalization and weighting set. The calculation types "Quick results", "Analysis" and "Monte Carlo Simulation" will be explained in more detail in Section 9. Finally, click "Finish" to begin calculation. Calculation time can vary, depending on the size of the product system and database, and the type of calculation (e.g. Monte Carlo Simulations take considerably longer than other calculations).

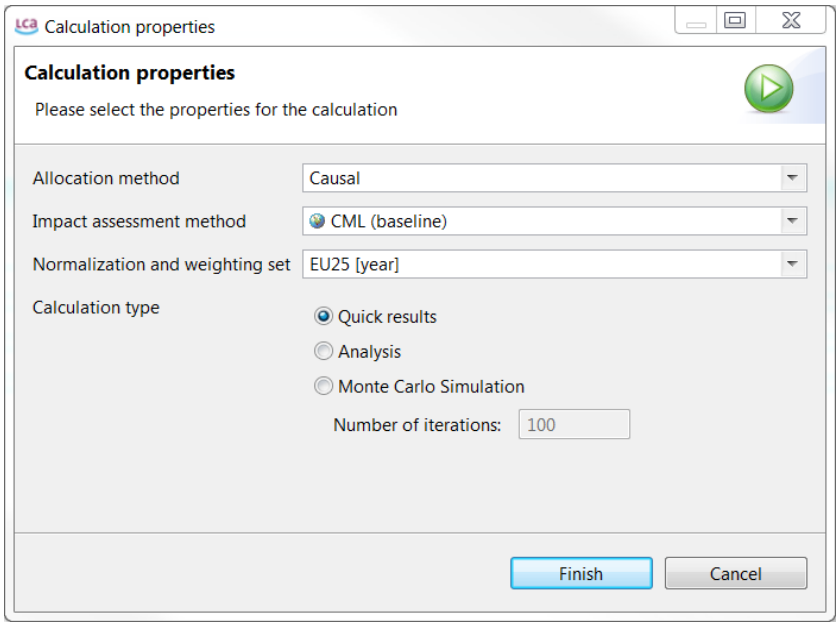


Figure 57: Calculating a product system, step 2

9 Result Analysis

This section will cover the three different calculation types "Quick results", "Analysis" and "Monte Carlo Simulation" and describe the information contained in each of the result edit tabs.

9.1 Quick results tab contents

The option “Quick results” provides information on direct impacts. Upstream impacts are not represented here (they are included in the Analysis results).

9.1.1 General information

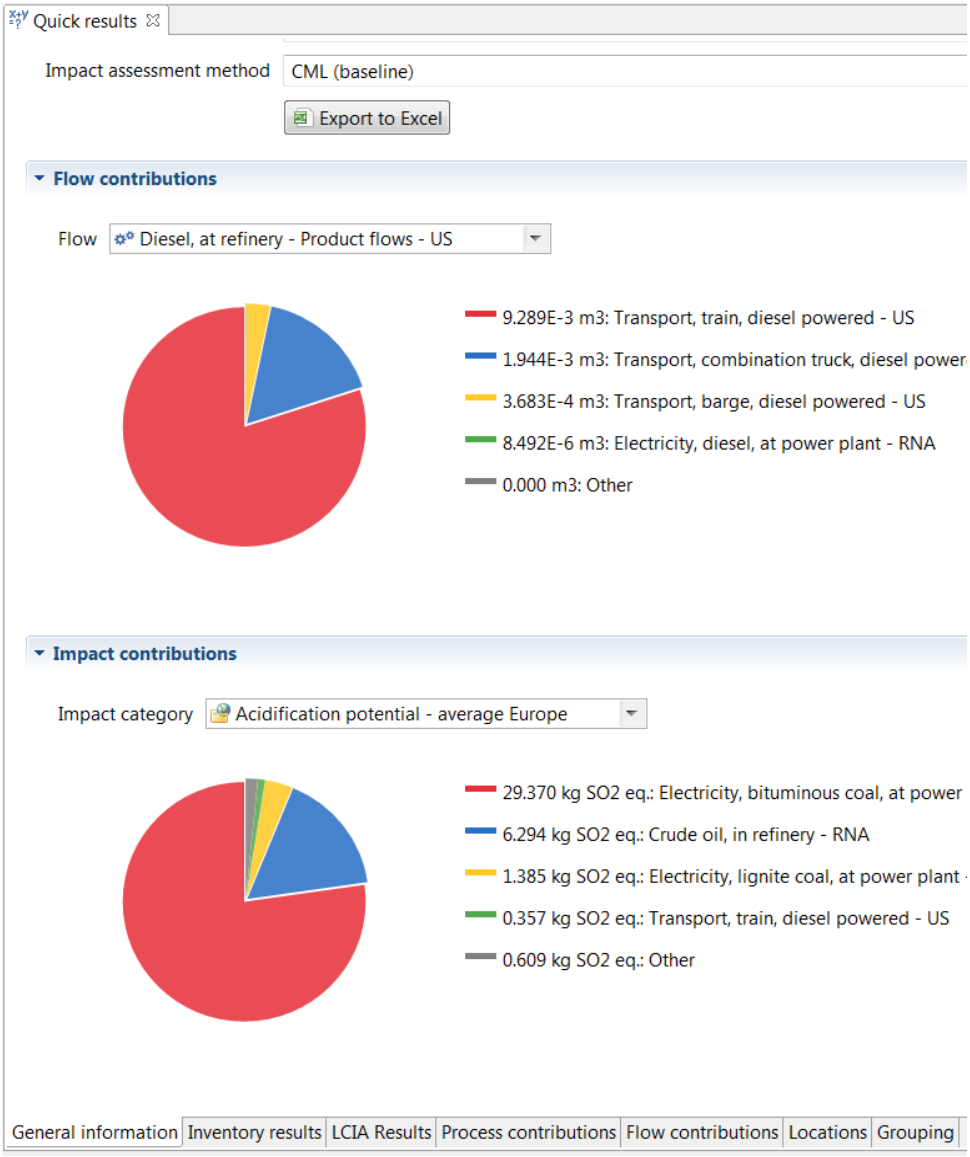


Figure 58: Quick results - General information tab

The General information tab displays which product system was calculated, including information on the allocation method, target amount and LCIA method used for the calculation. The "Flow contributions" section shows a pie chart illustrating the five processes with the highest direct contributions to the selected flow. Change the flow information displayed by selecting the desired flow from the list. Likewise, the "Impact category" section displays the five processes with the highest direct contributions to the selected impact assessment category.

9.1.2 Inventory results

Transport person diesel car | Quick results

Inventory results

Inputs

Flow	Category	Sub-category	Unit	Amount
Gas, natural	resource	ground-	m3	4.48347
Dummy, Disposal, solid waste, unspeci...	Product flows		kg	1033.44590
Dummy_Transport, pipeline, unspecifie...	Product flows		t*km	4.58603
Dummy, Energy, unspecified - RNA	Product flows		MJ	0.37509
Carbon dioxide, in air	resource	in air	kg	75.64380
Gasoline, combusted in equipment - R...	Product flows		m3	0.02243
Diesel, combusted in industrial boiler -...	Product flows		m3	0.04099
Liquefied petroleum gas, combusted i...	Product flows		m3	0.03014
Dummy, Disposal, solid waste, unspeci...	Product flows		kg	0.08608
Dummy_Ethylene glycol, at plant - RNA	Product flows		kg	0.10264
Dummy, Disposal, chemical waste, uns...	Product flows		kg	4.62442E-5
Diesel, combusted in industrial equipm...	Product flows		m3	0.00099
Petroleum refining, for olefins producti...	Product flows		kg	16.54310
Petroleum refining, for olefins producti...	Product flows		kg	2.29374

Outputs

Flow	Category	Sub-category	Unit	Amount
Benzene	water	unspecified	kg	0.19543
Lead	water	unspecified	kg	0.06853
Organic substances, unspecified	air	unspecified	kg	0.00578
Carbon dioxide, fossil	air	low population density	kg	9040.00000
NMVOC, non-methane volatile or...	air	unspecified	kg	64.26230
Nitrate	water	unspecified	kg	4.09890E-10
Sulfide	water	unspecified	kg	0.00604
Particulates, > 2.5 um, and < 10um	air	high population density	kg	6.80000E5
Chloride	water	unspecified	kg	4197.25585
Thallium	water	unspecified	kg	0.00138
Petroleum coke, at refinery - RNA	Product flows		kg	1901.63934
Oils, unspecified	water	unspecified	kg	2.71151
Cobalt	water	unspecified	kg	0.00258
Ammonium ion	water	unspecified	kg	4.14375E-7

General information | Inventory results | LCIA Results | Process contributions | Flow contributions | Locations | Grouping

Figure 59: Quick results - Inventory results tab

The inventory results tab contains a table of all of the product system's inputs and outputs, displaying the amounts and units for each entry (in random order). To see the list of flows in alphabetical order, simply click on "Flow". Likewise, to have the table organized according to category, sub-category, unit or amount, click on those respective cells at the top of the table. The information presented in all openLCA tables can be copied from the openLCA editor and pasted elsewhere (e.g. in excel, notepad, etc.). To find out more, see Section 4.6.6.

9.1.3 LCIA results

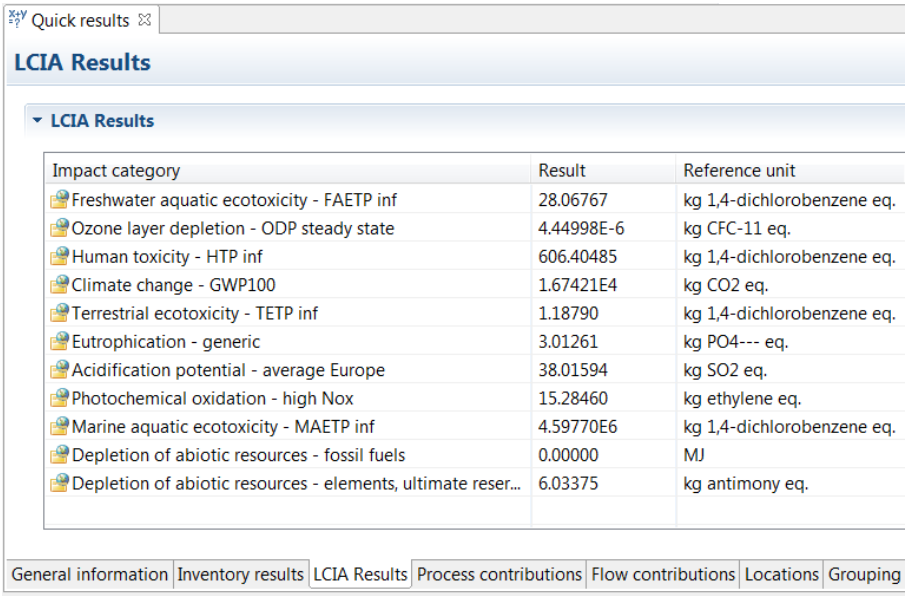


Figure 60: Quick results - LCIA Results tab

This tab will be included in the quick results in the case that an impact assessment method was selected in the calculation wizard. The table lists the results and reference units for the respective impact assessment method categories.

9.1.4 Process contributions

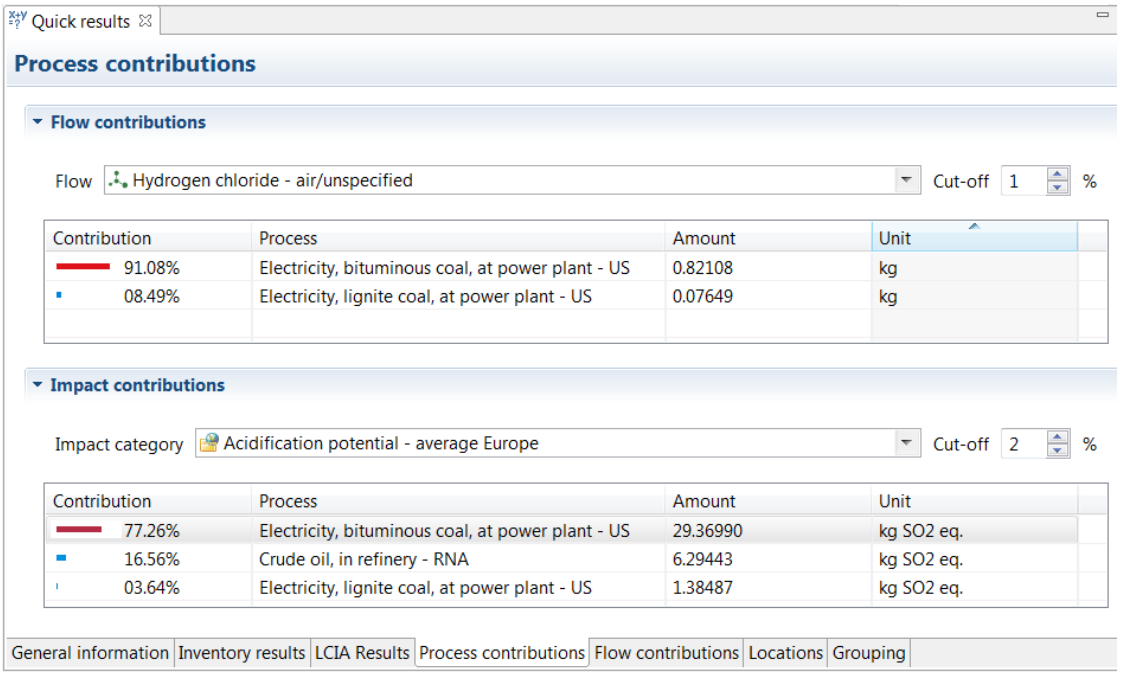


Figure 61: Quick results - Process contributions tab

The process contributions tab contains the same information displayed in the pie charts on the general information tab, but here it is possible to see not only the five main contributors but all processes that contribute to direct impacts for flows and impact categories, respectively. Select for which flow/impact

category the process contribution information should be displayed by selecting the desired flow/impact category from the list. It is also possible to set a cut-off. The cut-off refers to the percent value in the "Contribution" column. Only contributions above the set cut-off value will be displayed in the table.

9.1.5 Flow contributions

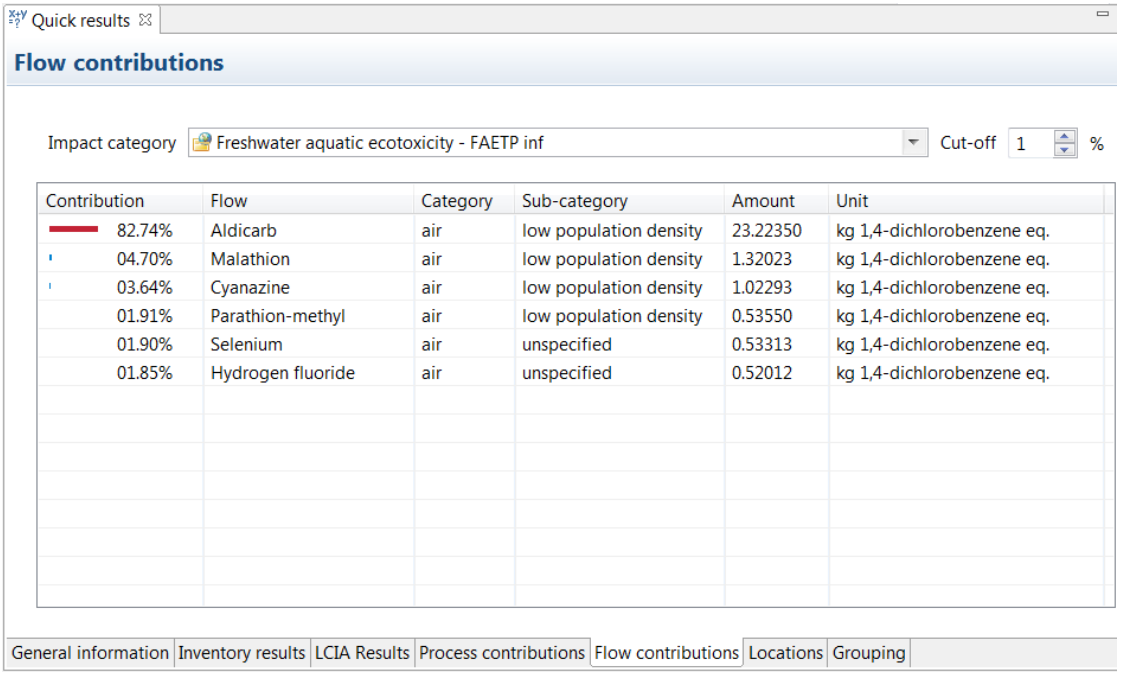


Figure 62: Quick results - Flow contributions tab

The flow contributions tab displays the direct contributions of flows to all impact categories. Select the impact category you are interested and the flows contributing to that category will be listed with their respective values. Use the Cut-off option to filter flows with low contributions.

9.1.6 Locations

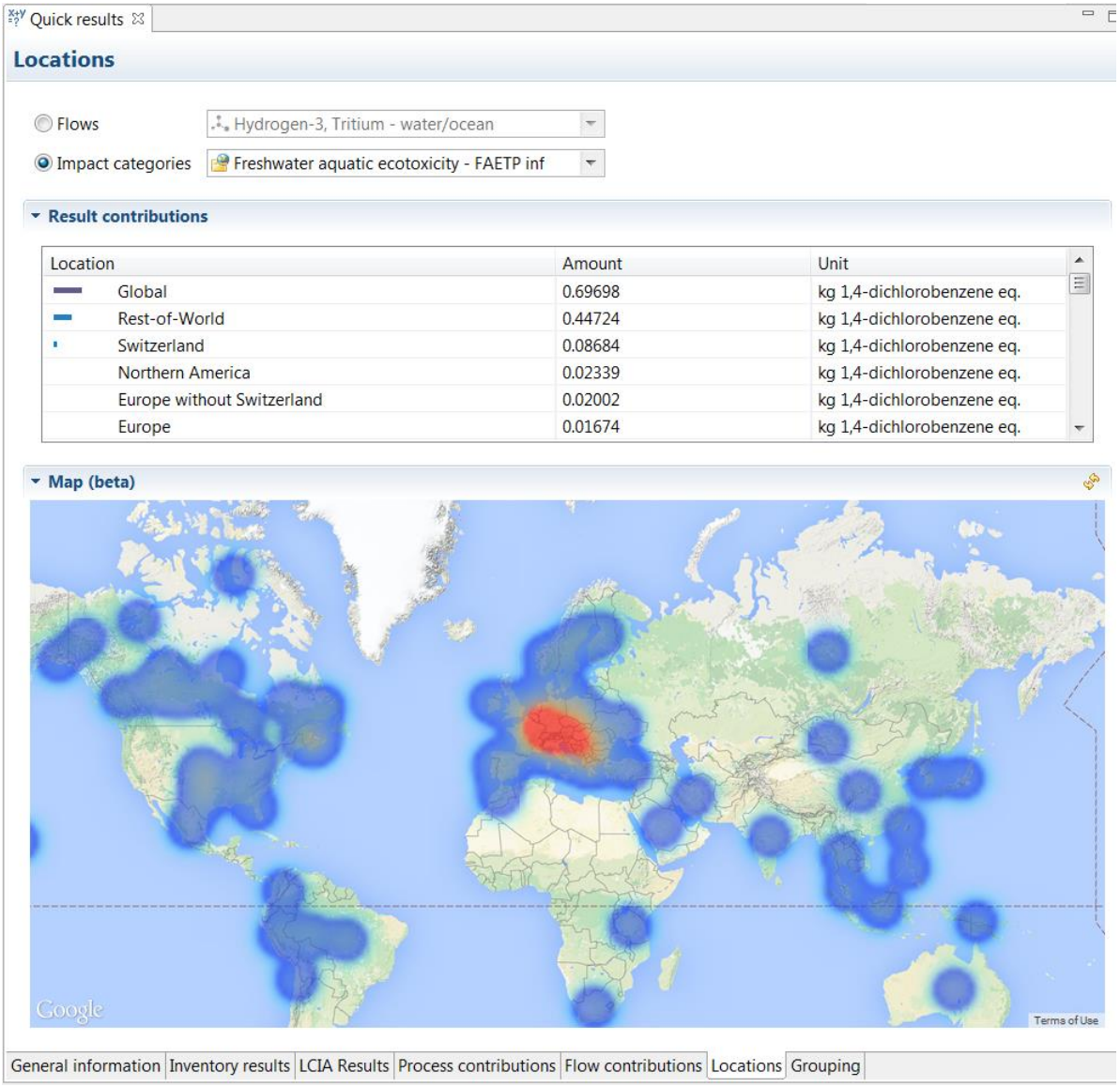


Figure 63: Quick results - Locations tab

The location tab illustrates specific information on localized flows and impact categories. The locations are set in the flow level in openLCA.

9.1.7 Grouping

In openLCA, it is possible to group processes in order to see the cumulative values for processes. Please note, the values shown in the “Grouping” tab are the direct impacts (i.e. not including upstream values).

To create a new group, select the green “+” icon in the right-hand corner of the editor. Then name the new group (Figure 64).

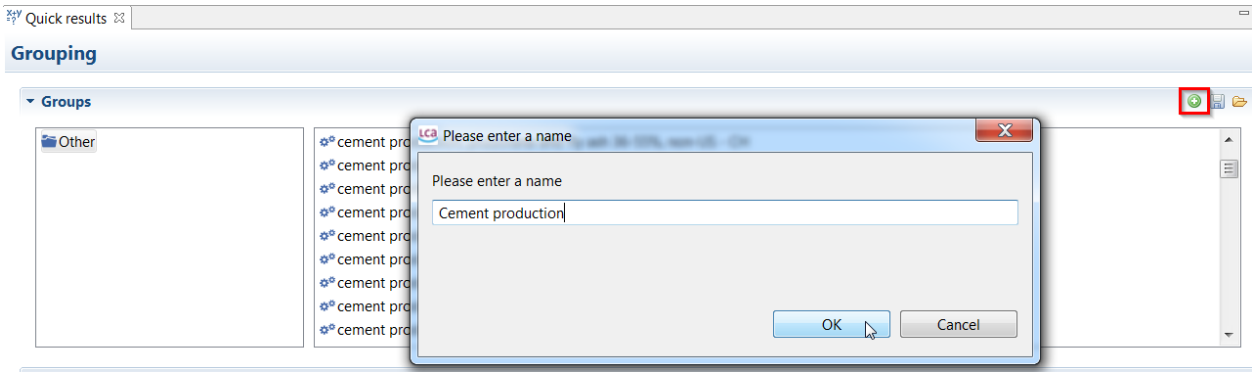


Figure 64: Creating a new group, step 1

To move a process to a group, right click on the process and select “move” and then the desired group. To select more than one process at once click on one, hold the “shift” key on your keyboard, and then scroll and select another process. All processes in between will also be selected.

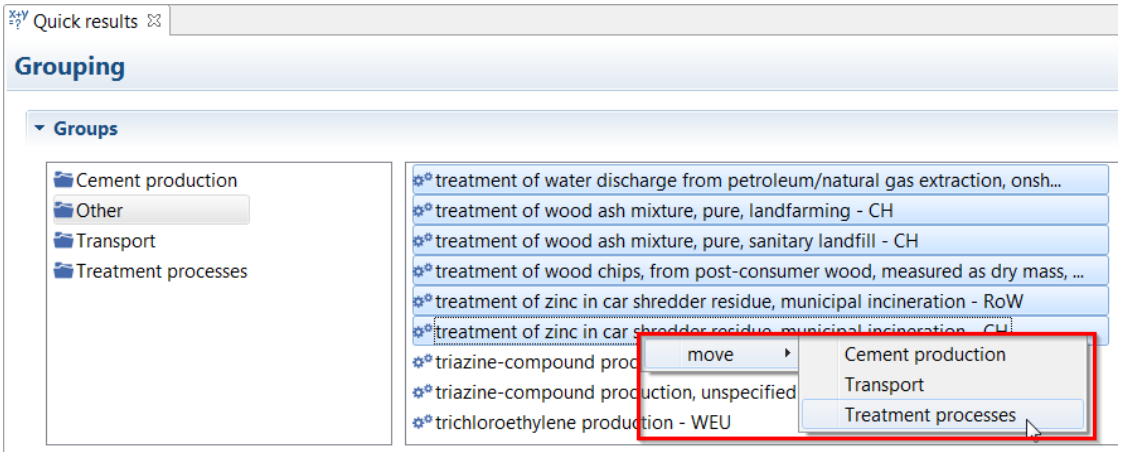


Figure 65: Creating a new group, step 2

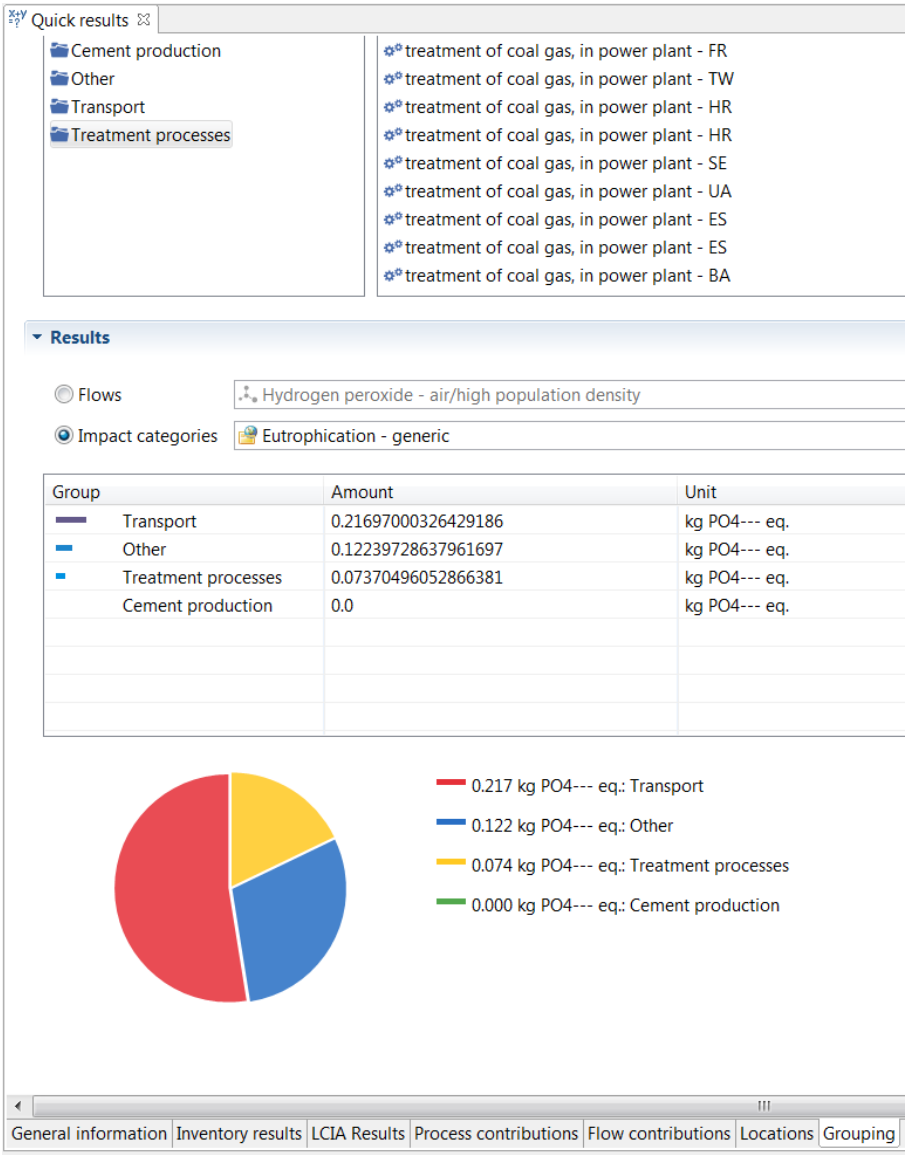


Figure 66: Quick results - Grouping tab

Once you have created groups and added processes to them, the process contributions for specific flows and impact categories will be displayed in the table and as a pie chart. Please note, the contributions displayed are direct, which means without upstream contributions. To take upstream contributions into account it is necessary to include all upstream processes in the group.

As it can be time-consuming to create new groups, you have the option to save groups in the Grouping tab. To do so, click on the “Save” icon in the top right-hand corner of the Grouping editor. Then give the group a name and press ok. These groups will be available in the Quick results editor each time you carry out a quick results or analysis calculation for any product system.

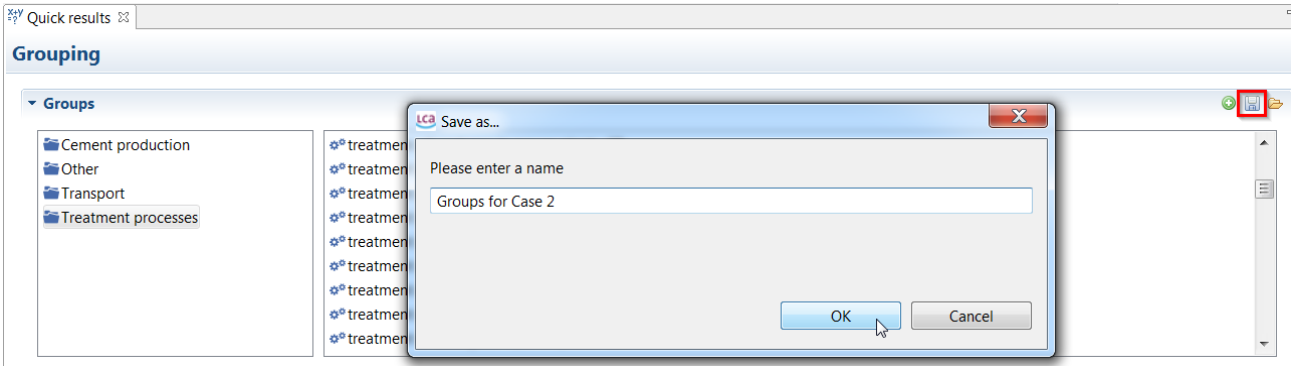


Figure 67: Saving groups

To open saved groups, click on the icon of the open folder in the top right-hand corner of the Grouping tab.

9.2 Analysis tab contents

The option “Analysis” provides information on direct as well as upstream impacts. All of the tabs with information on direct impacts from the quick results are included in the analysis. Upstream impacts are shown in the tabs “Process results”, “Contribution tree” and “Sankey diagram”

9.2.1 General information

The General information tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.1.

9.2.2 Inventory Results

The Inventory results tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.2.

9.2.3 LCIA Results

The LCIA Results tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.3.

9.2.4 Process contributions

The Process contributions tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.4.

9.2.5 Process results

The Process results tab is unique to the Analysis calculation. Here, both the direct and the total upstream contributions are displayed. In the section “Flow results”, select a process from the list and the input and output flows that contribute to that flow will be listed. Select a process from the list in the section “Impact assessment results”. All of the impact categories of the chosen impact assessment method will be listed along with the values for which that the selected process contributes to each impact category.

Direct contributions/impacts are those resulting from that specific process only. Upstream total is the sum of direct and upstream contributions/impacts.

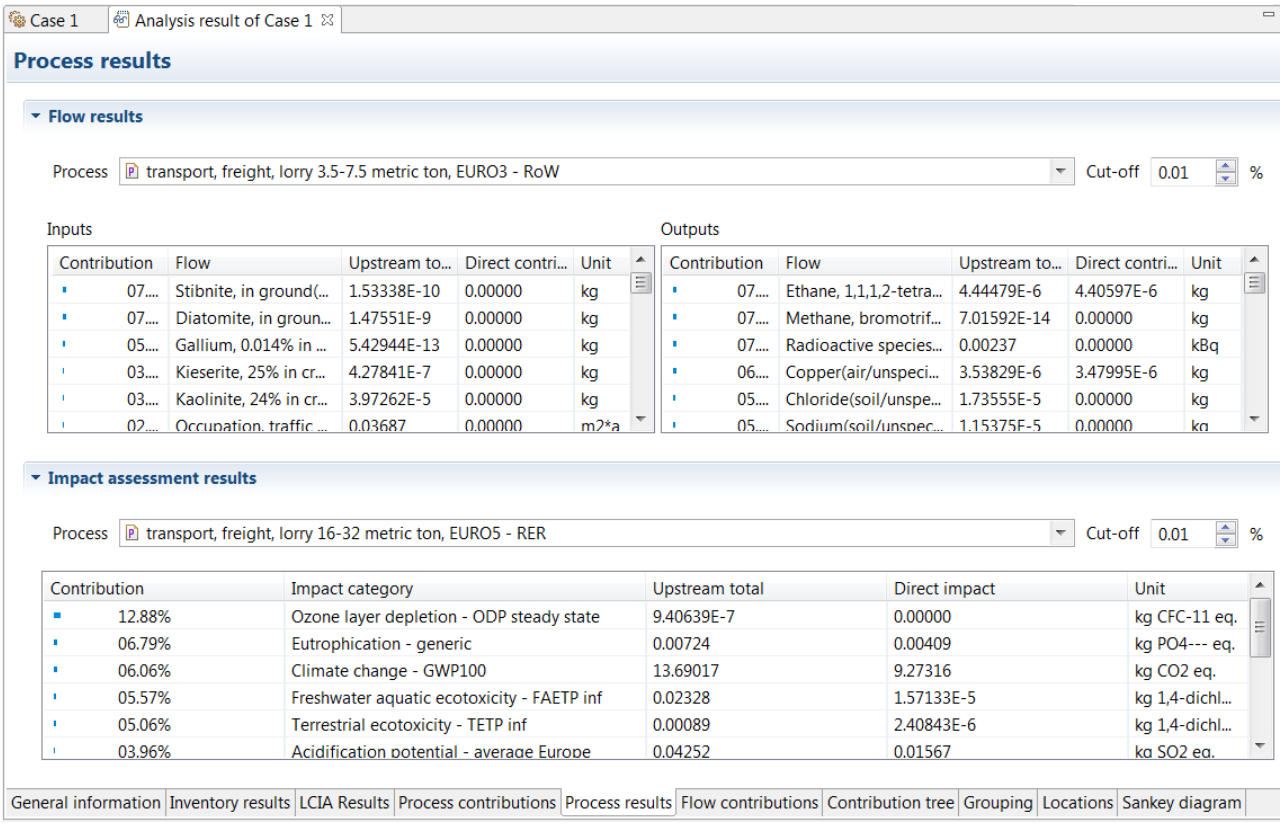


Figure 68: Analysis - Process results tab

9.2.6 Flow contributions

The LCIA Results tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.5.

9.2.7 Contribution tree

The contribution tree is unique to the Analysis calculation. It breaks down process contributions to flows and impact categories, displaying upstream totals.

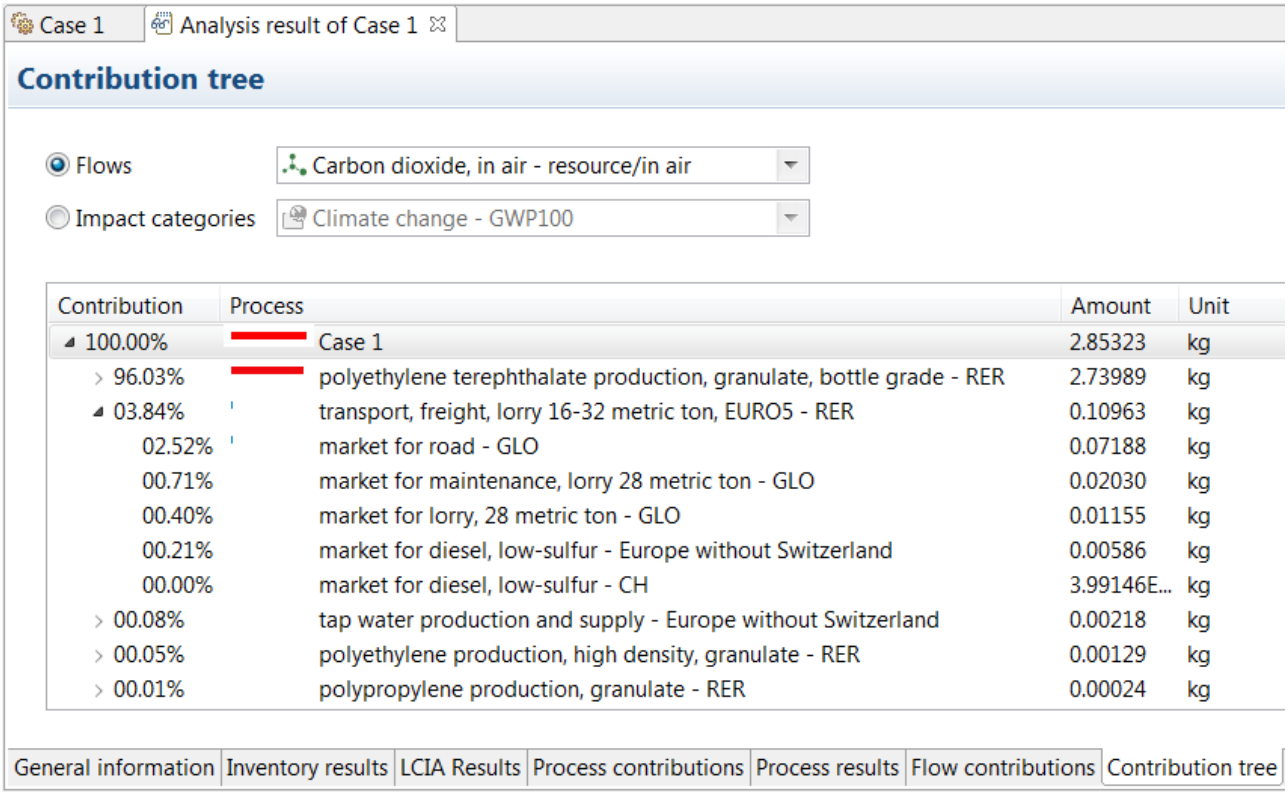


Figure 69: Analysis - Contribution tree tab

9.2.8 Grouping

The Grouping tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.7.

9.2.9 Locations

The Locations tab of the Analysis contains the same information as for “Quick results”. For more information, see Section 9.1.6.

9.2.10 Sankey diagram

The Sankey diagram is a graphical illustration of the impacts of processes in the product system to specific flows/impact categories. Right-click anywhere in the Sankey diagram editor and select “Set Sankey diagram options” to select the flow or impact category and cut-off level to be displayed (Figure 70).

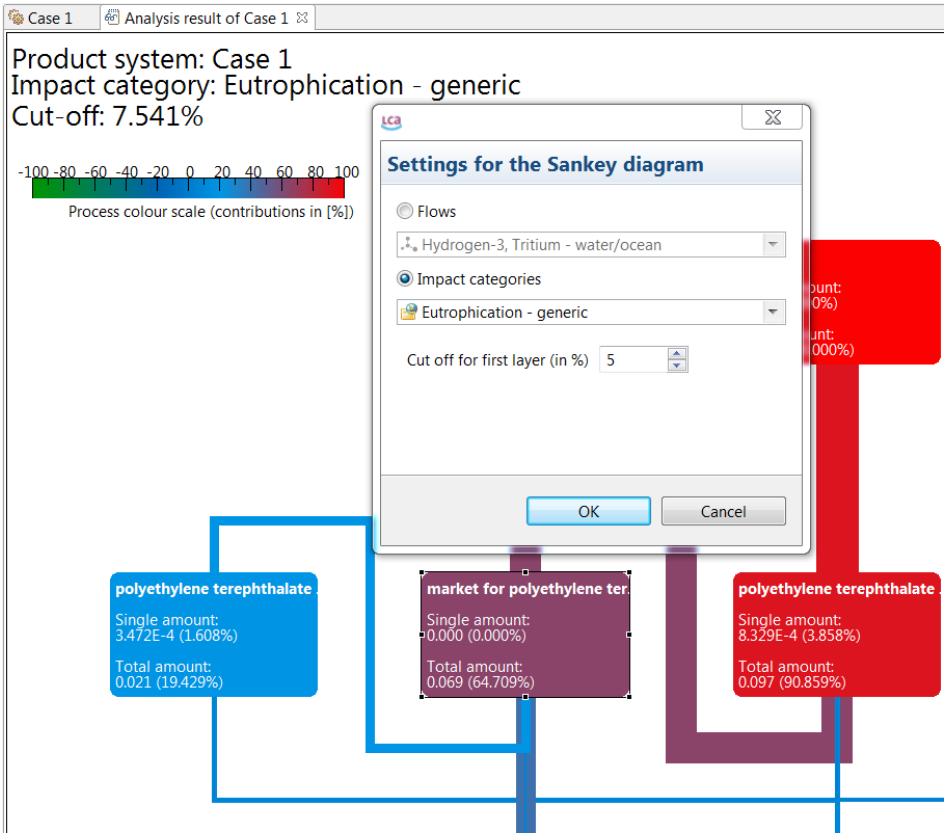


Figure 70: Analysis - Sankey diagram

In the Sankey diagram, the “Single amount” refers to the direct contribution of the process while “Total amount” is the upstream total contribution of the process. To open up a process in a new editor tab, simply double-click on it.

Five icons in the top left hand of the software give you different options for working with the Sankey diagram:

- diagram viewer that provides an overview of the diagram with zoom options (Figure 71). The blue box in the viewer shows the view displayed in the Analysis editor.
- set Sankey diagram options
- save Sankey diagram as PNG file
- zoom in and out of the Sankey diagram

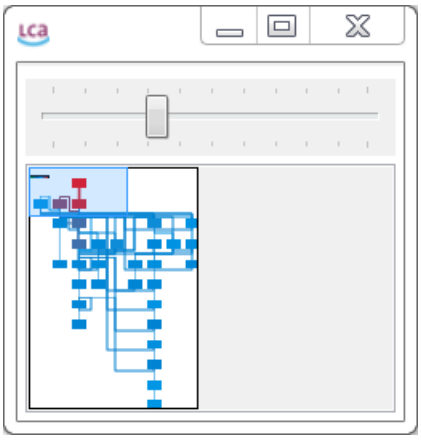


Figure 71: Sankey diagram viewer

9.3 Monte Carlo Simulation

A Monte Carlo simulation varies entry data of the model calculation randomly according to the uncertainty distributions. Then, an uncertainty distribution for the calculation result is provided. In general, several thousand iteration passes are usually required.

9.3.1 Adding uncertainty information

The first step in openLCA is to add uncertainty data to all flows in the processes (distribution, standard deviation, min/max, etc). For the reference output no uncertainty distribution is assumed. It is also possible to define uncertainty data for parameters as well as LCIA characterization factors.

To add uncertainty data to flows, open up a process and select “Edit” in the uncertainty field of a process:

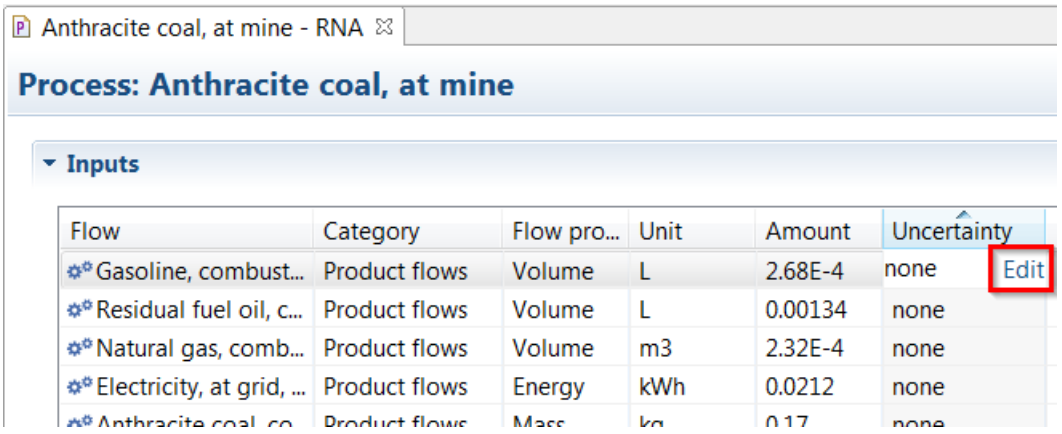


Figure 72: Adding uncertainty information, step 1

Then, select the uncertainty distribution (no distribution, logarithmic normal, normal, triangle or uniform) as well as the geometric mean and geometric standard deviation:

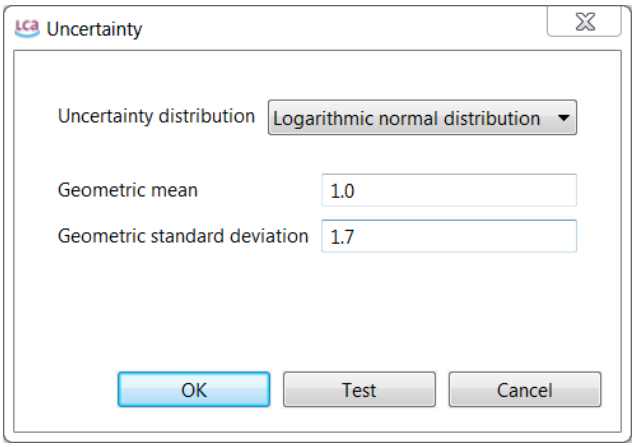


Figure 73: Adding uncertainty information, step 2

To add uncertainty information to LCIA characterisation factors, click on the “Edit” button in the “Impact factors” tab of the impact assessment method:

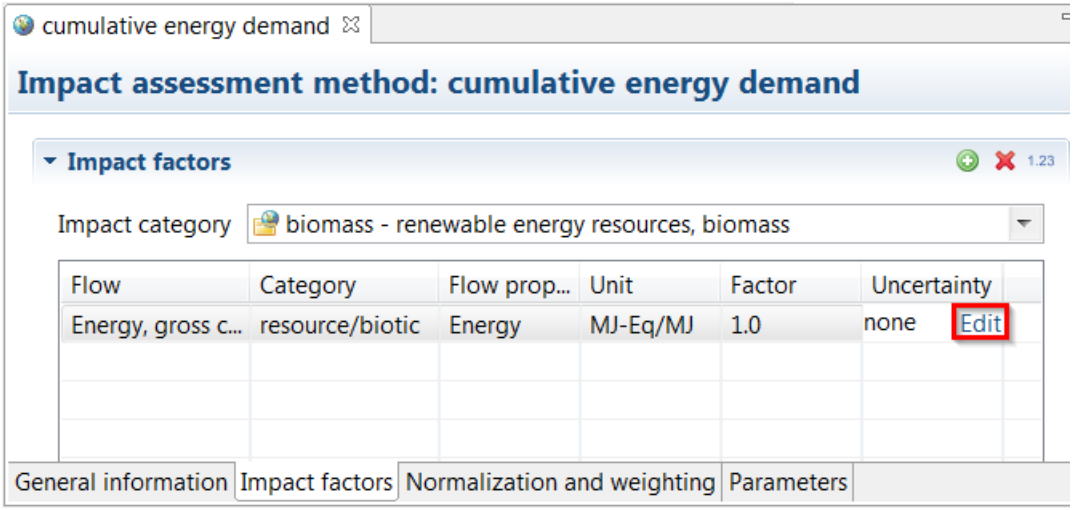


Figure 74: Adding uncertainty information to LCIA characterisation factors

Uncertainty information can be added to parameters in the same manner (in the parameters tab of processes, LCIA methods and product systems).

9.3.2 Starting the Monte Carlo Simulation

To carry out Monte Carlo Simulation, select it in the wizard when calculating a product system, as well as the number of simulations to be carried out. Then, uncertainties are calculated for each flow and impact category.

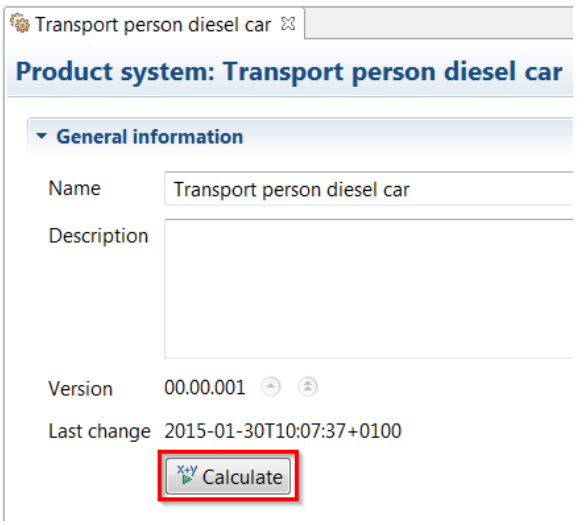


Figure 75: Monte Carlo Simulation, step 1

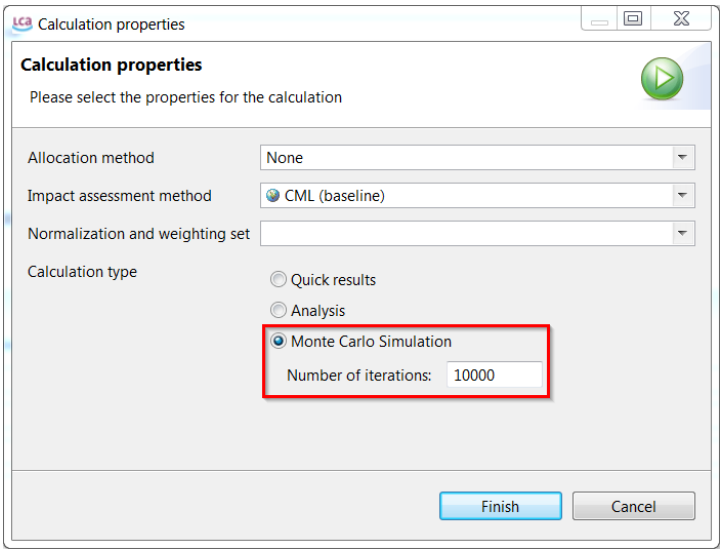


Figure 76: Monte Carlo Simulation, step 2

The Simulation will open up in the editor. Select “Start” to begin calculations (Figure 77). The calculation time required depends on database and product system complexity, and selected number of simulations.

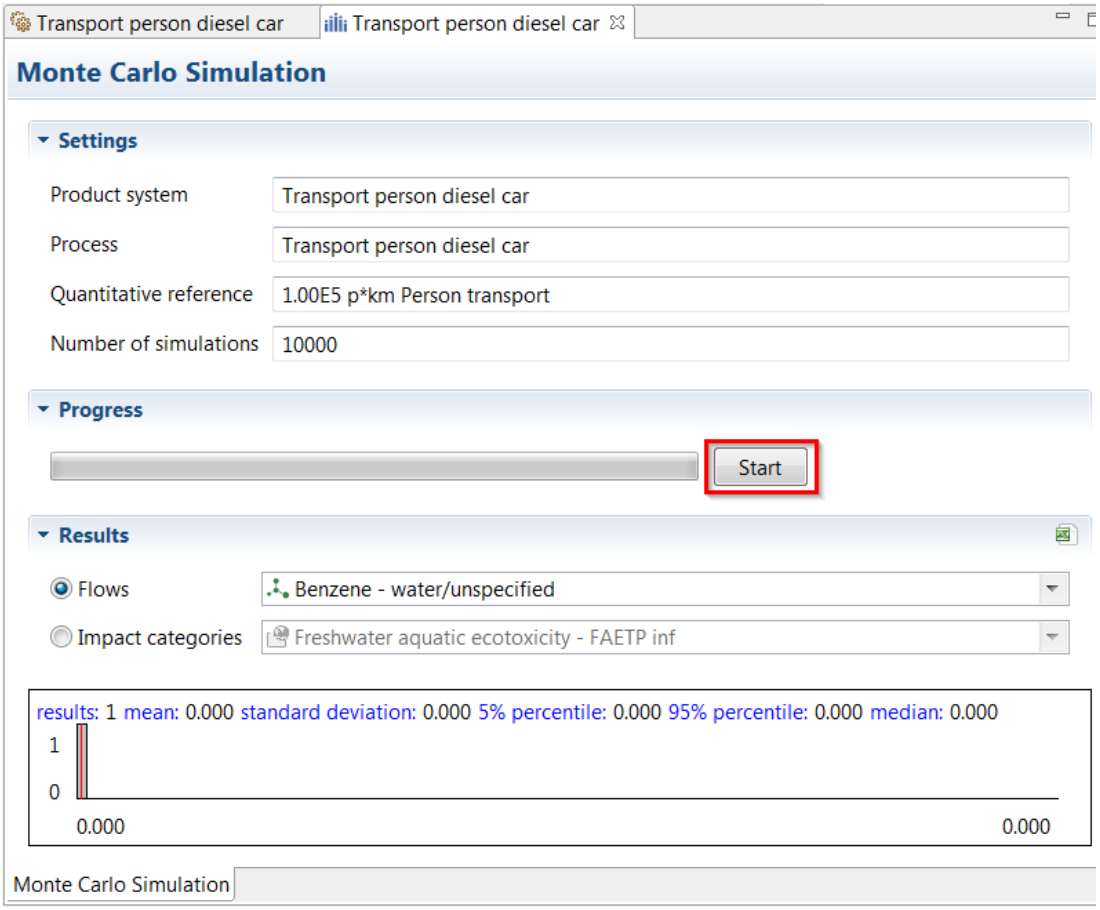


Figure 77: Monte Carlo Simulation, step 3

The results for each flow and impact category will be displayed while the simulation runs.

9.3.3 Monte Carlo Results

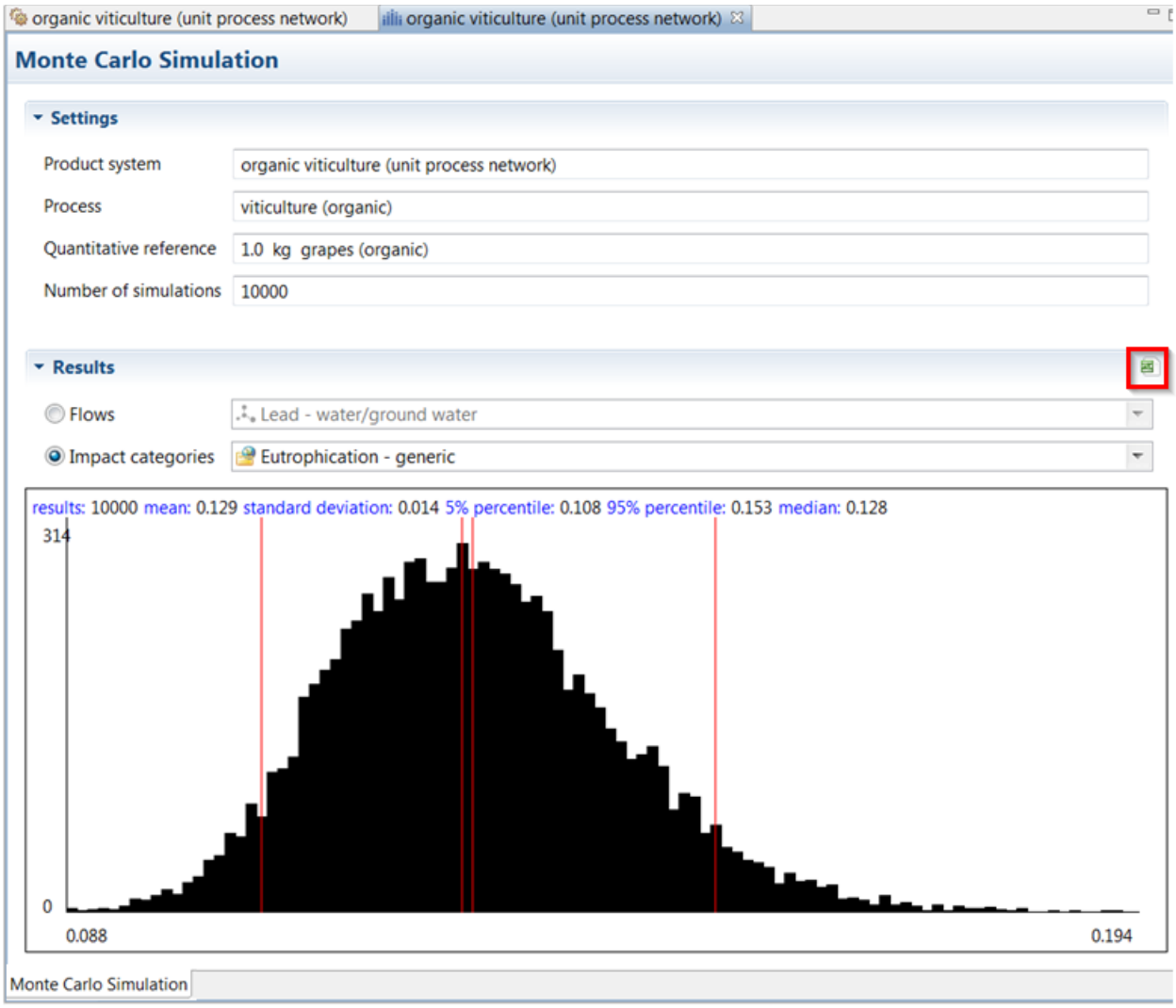


Figure 78: Monte Carlo Simulation results

The results of the simulation can be exported as an excel document. Simply click on the excel icon on the right-hand side of the editor (as shown in Figure 78).

10 Projects

In general, projects can be used to compare product systems.

10.1 Creating a new project

To create a new project, begin by right-clicking on the "Projects" folder and select "New project".

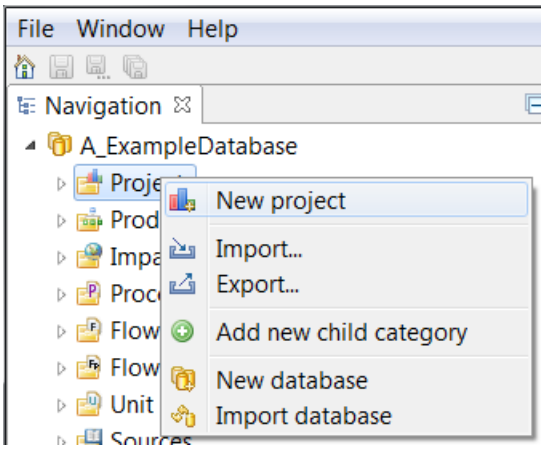


Figure 79: Creating a new project, step 1

Name the new project and provide a description (optional):

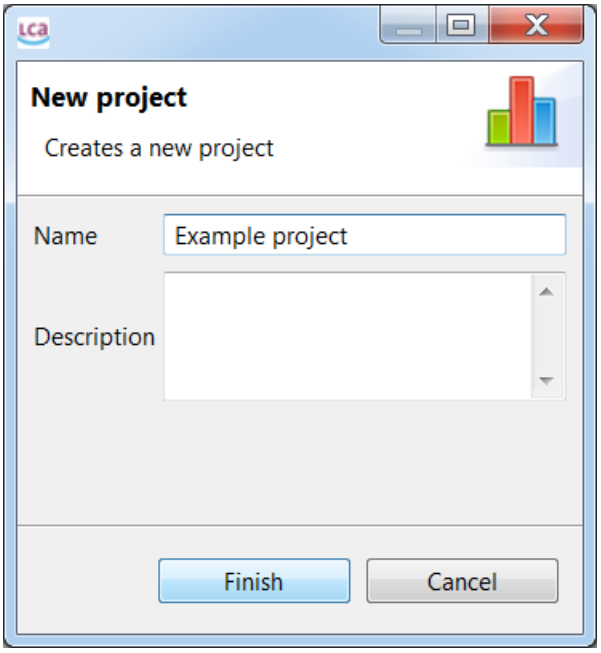


Figure 80: Creating a new project, step 2

The new project will open up in the Editor

10.2 Project tab contents

10.2.1 Project setup

In the “General information” section you can type in a name for the project and a description. Once you have configured your report in the “Project setup” and “Report sections” tabs, click on the “Report” button to have the software carry out the calculation and create your report.

In the “LCIA Method” section select the method for the calculation as well as a normalization and weighting set, if applicable (you will be able to select from the methods you have imported in that

particular database). You also have the option to select the impact categories you would like to have displayed in the report (Figure 81).

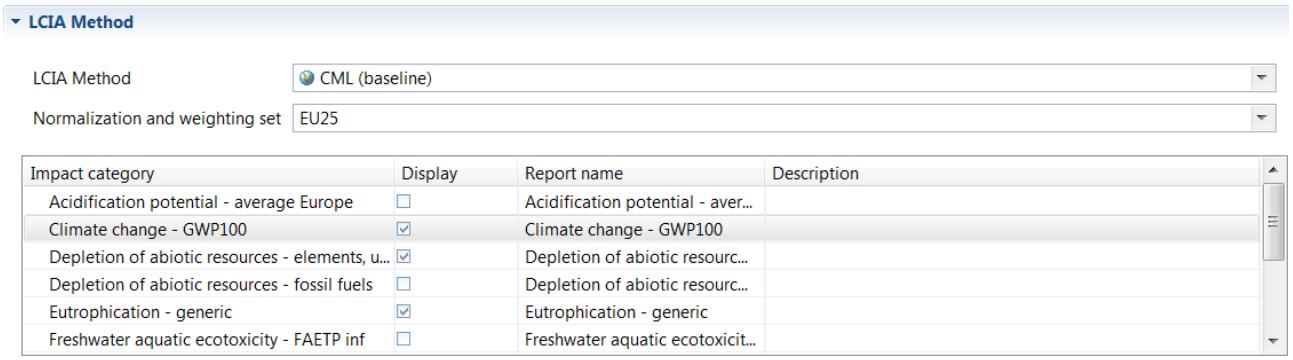


Figure 81: Project setup, LCIA method selection

In the "Variants" section, click on the green "+" icon on the right to add product systems you want to compare. Each selected product system acts as a 'variant' for the calculation. It is possible to select the same product system multiple times and/or different product systems. For each variant, you can then select a new name, if desired, as well as a different allocation method and amount. For example, to compare the results of a product system calculation using three different allocation methods, select the same product system three times and then select a different allocation method for each:

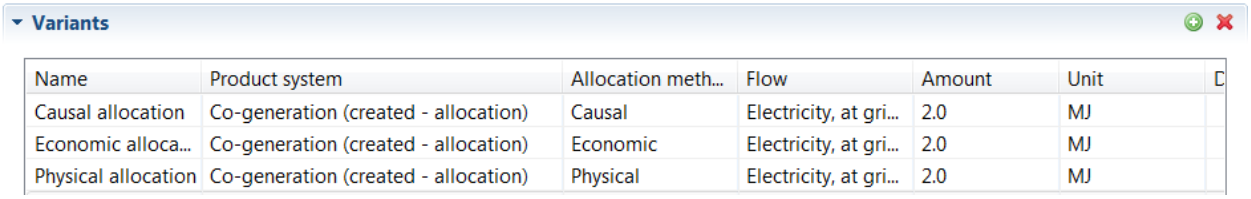


Figure 82: Project setup, Variants

In the "Parameters" section, it is possible to change parameter values for variants. For example, let's say we want to compare the impacts of a diesel car when it consumes 6, 8 or 10 litres per 100km. I can select a product system for a diesel car that contains a parameter for the diesel consumption ('cons') three times in the "Variants" section. Rename each variant (see next figure). Then in the "Parameters" section add the parameter 'cons' by clicking on the green "+" button on the right and selecting the correct parameter from those available. Then enter a new parameter value for each variant:

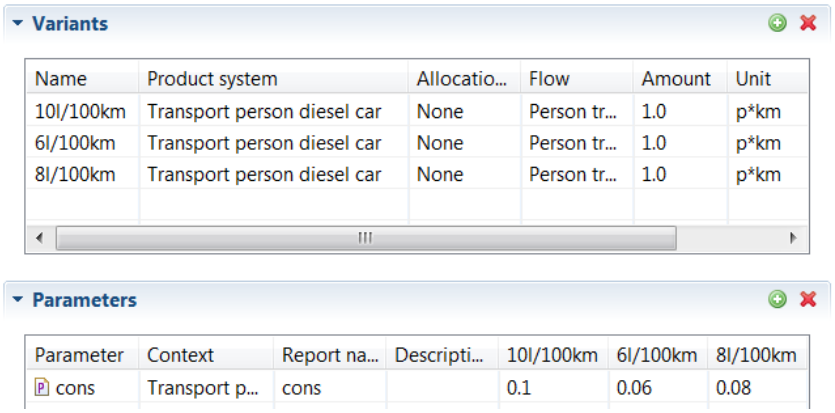


Figure 83: Project setup, Parameters

In the "Process contributions" section you can select processes whose impacts should be displayed separately in the report. Select processes using the green "+" icon on the right. You can then change the name shown in the report under "Report name", if desired. Please note that the results shown are direct (single indicator) results, not including upstream processes. The process contributions will be displayed in the report in a diagram:

Figure 84: Project setup, Process contributions result example

10.2.2 Report sections

In this tab you can configure the report that will be created when you click on the "Report" icon in the "Project setup" tab. Here you can name the report and add/delete report sections. As per default, a

report contains the sections ‘Introduction’, ‘Project Variants’, ‘Selected LCIA Categories’, ‘LCIA Results’, ‘Single Indicator Results’, ‘Process contributions’, and ‘Relative Results’. You can rename sections and edit the description text for each section. Delete sections by selecting the red “X” icon on the right. Change the order of sections using the up/down icons on the right. It is also possible to select a component for each section, for example, which type of chart or table should be displayed. Once you have all sections configured, make sure to save the project before creating the report. (Create a report by selecting the “Report” icon in the “Project setup” tab).

10.3 Exporting a project report

Once a report has been generated, a “Report Viewer” window will automatically open up in the editor. Select the “Export report” icon in the top left-hand corner to export this report in html format.

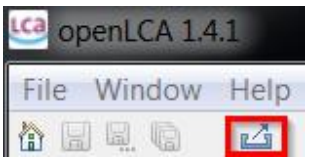


Figure 85: Exporting a report in html format

11 Advanced Topics

11.1 Expanding memory on a MacOS system

To expand memory on a mac, begin by opening the “Finder”, then “Applications” and find openLCA. Right-click on openLCA and select “Show package contents”:

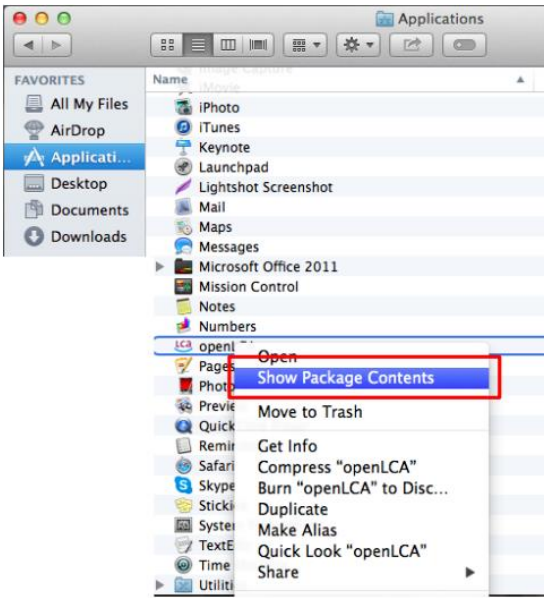


Figure 86: Expanding memory on a mac, step 1

Then open the file “Contents”, then the file “MacOS”. Double click on the file “openLCA.ini” (if the text

editor is not automatically opened, select the program “Text Edit” manually). In the editor, change the memory manually, for example to 4096M. Then close all windows and restart openLCA.

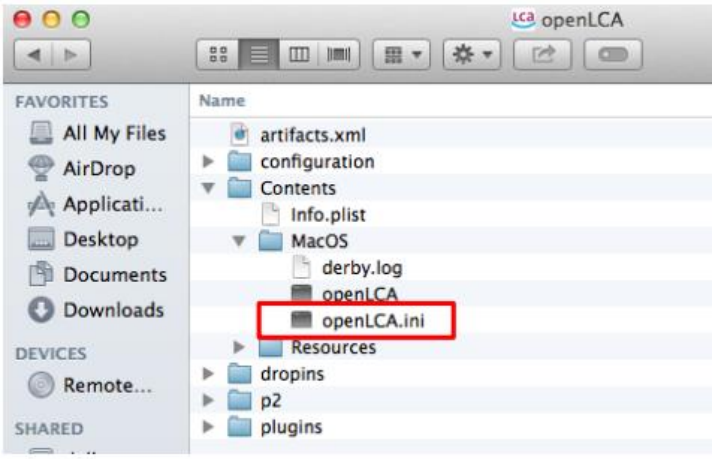


Figure 87: Expanding memory on a mac, step 2

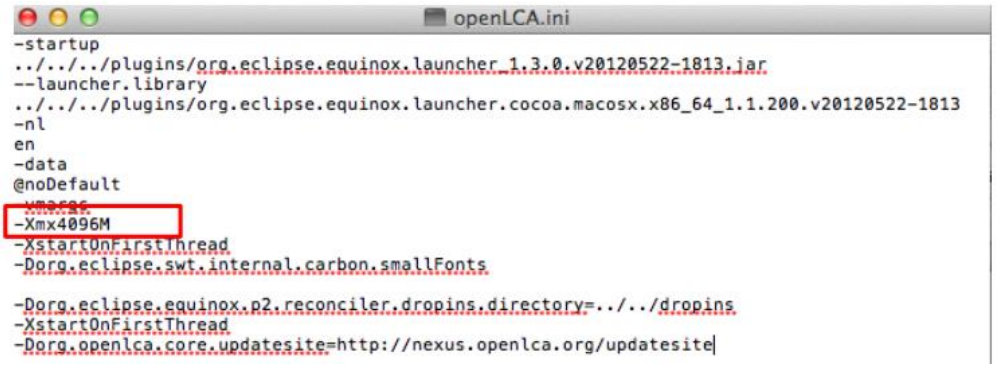


Figure 88: Expanding memory on a mac, step 3

11.2 Scripting in openLCA

With version 1.4.1, openLCA now supports the possibility to run Python and JavaScript programs directly in openLCA. With this feature you can automate calculations in openLCA, write your own data imports or exports, perform sensitivity analysis calculations by varying parameter values, and much more. You can find the scripting feature under the developer tools menu in openLCA:

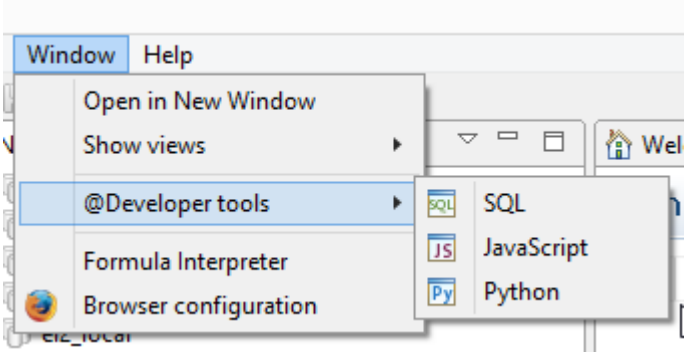


Figure 89: Accessing scripting

As shown in Figure 89, just click on the language you want to use and an editor will open where you can

write your scripts. To make debugging output visible, we directly connected the openLCA logger to the scripting environment. Thus, when you write scripts it is helpful to open the logging console in openLCA (File/Preferences/Logging):

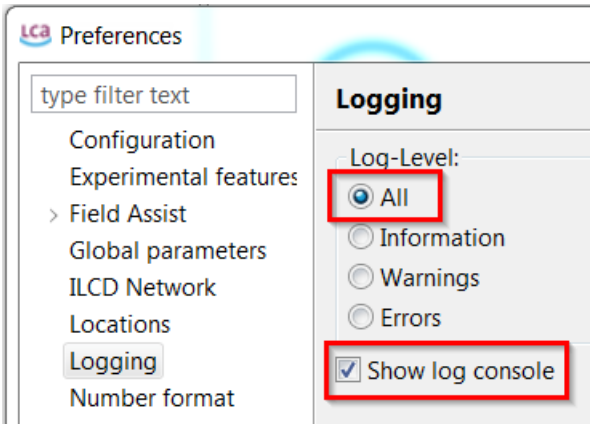


Figure 90: openLCA logger for scripting

After this we can execute our first script (note that it takes a bit to initialize the Python interpreter when you execute a script the first time in your current openLCA session). Just write the following text in the editor and press the run button in the toolbar:

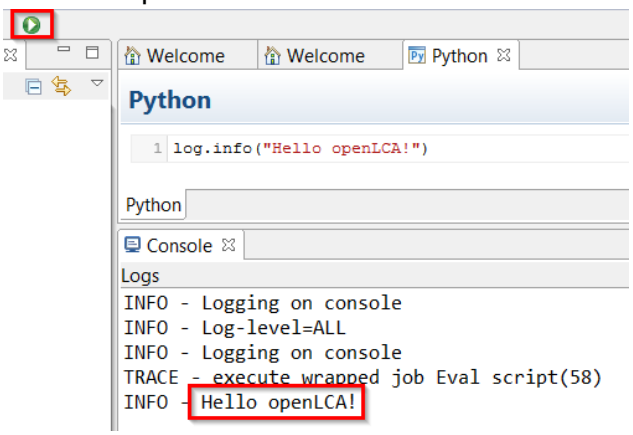


Figure 91: Running script example

We can also log an error via

```
log.error("Hello openLCA")
```

This will show an error popup in openLCA:

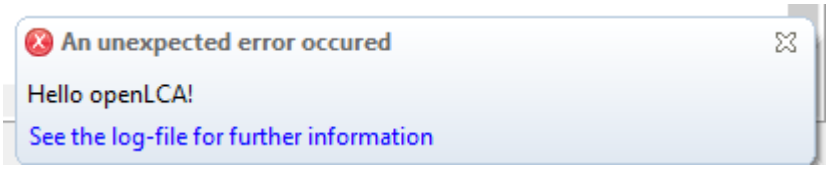


Figure 92: Error popup

As it is written in the popup, these logs are also written to the openLCA log-file which you can find in

your user directory.

11.2.1 The Python interpreter

openLCA integrates Jython 2.7 (http://www.jython.org/) as Python interpreter. Python is a fully featured programming language that supports imperative, object oriented, and functional programming paradigms. Additionally, Python is very easy to learn so that you can quickly get started. Jython also comes with a powerful part of the Python standard library. For example, you can use the csv module (http://www.jython.org/docs/library/csv.html) to read and write csv files directly in openLCA:

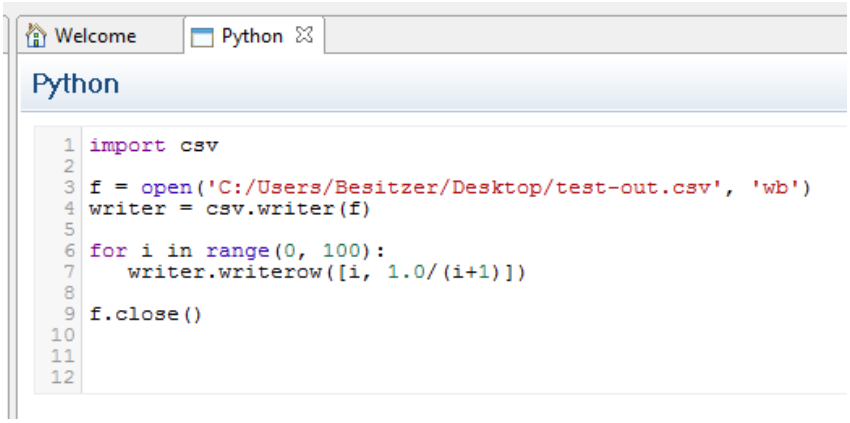


Figure 93: Read and write csv files in openLCA

11.2.2 The JavaScript interpreter

The JavaScript interpreter that openLCA uses directly comes with the Java 8 runtime which is included in openLCA (http://www.oracle.com/technetwork/articles/java/jf14-nashorn-2126515.html). Like Python, JavaScript is a programming language that supports imperative, object oriented, and functional programming paradigms. Due to the modern web, JavaScript is currently one of the most popular programming languages. Note, that the JavaScript runtime in openLCA fully supports the JavaScript language but that the runtime platform is not the browser but openLCA (i.e. there is no window-object or DOM as in a web-browser). However, you can load other JavaScript files; e.g. you could use math.js (http://mathjs.org) in openLCA via the load-function (the same works with execfile for Python):

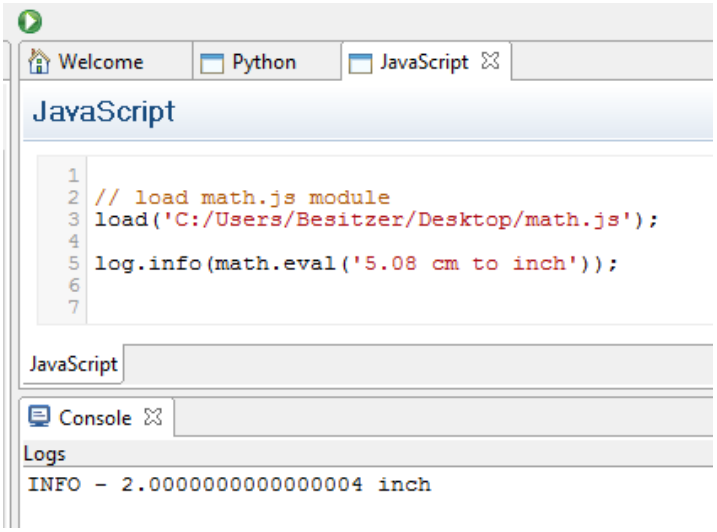


Figure 94: Loading JavaScript files

11.2.3 The olca-object and the inspection function

To provide an entry point to the openLCA API[3] you have access to an object with the name *olca* which provides a set of useful methods. For example you could log the names of all processes in a database with the following Python script[4]:

```
for descriptor in olca.getProcessDescriptors():
log.info(descriptor.name)
```

One of the most useful methods of the *olca*-object is the *inspect* function which takes an object as an argument and writes the object´s protocol to the logging console. For example, if we want to know which methods we can call on a process descriptor object we could write:

```
olca.inspect(olca.getProcessDescriptors()[0])
```

This will take the first process descriptor object from the database (or give an error if we do not have a process in the currently opened database) and print the protocol of the object to the logging console:

```
protocol:
  compareTo(BaseDescriptor) : int
  compareTo(Object) : int
  equals(Object) : boolean
  getCategory() : Long
  getClass() : Class
  getDescription() : String
  getId() : long
  getLocation() : Long
  getModelType() : ModelType
  getName() : String
  getProcessType() : ProcessType
  getQuantitativeReference() : Long
  getRefId() : String
  hashCode() : int
  isInfrastructureProcess() : boolean
  notify() : void
```

[3] API stands for Application Programming Interface
[4] Note that you need to open a database when you want to access data via the script API.

```
notifyAll() : void
setCategory(Long) : void
setDescription(String) : void
setId(long) : void
setInfrastructureProcess(boolean) : void
setLocation(Long) : void
setName(String) : void
setProcessType(ProcessType) : void
setQuantitativeReference(Long) : void
setRefId(String) : void
setType(ModelType) : void
toString() : String
wait() : void
wait(long) : void
wait(long, int) : void
```

In this protocol each line describes a method you can call in the following form:

```
[method name] ( [type of argument 1] [type of argument 2] ... ) : [return type]
```

For getter methods with no arguments we can use a simplified form in the Python interpreter: instead of

```
descriptor.getName()
```

we can also write

```
descriptor.name
```

To see the methods of the olca-object we can also call the inspect method on the olca-object itself:

```
olca.inspect(olca)
```

In the protocol that is now written to the console we can see for example the following method:

```
getProcess(String) : Process
```

This means that we can get a process for a string (which is the name of the process). The following script will load the process with the name “compost plant, open” from the database and write the process name and protocol to the console:

```
process = olca.getProcess("compost plant, open")
log.info(process.name)
olca.inspect(process)
```

11.2.4 Modifying database content

The *olca*-object also contains methods like *insertProcess* or *updateProcess* which – like the names say – will insert a new process object or update an existing process in the currently opened database. The following example loads the process with the name p1 from the databases, clears the current parameter list of this process, adds 10 new parameters to this process, and finally updates this process in the

database:

```
# get the process p1 from the database
process = olca.getProcess("p1")

# remove the current process parameters
process.parameters.clear()

for i in range(1, 11):
    # create a new parameter object
    param = Parameter()
    param.name = "p%s" % i
    # set it as an input parameter
    param.inputParameter = True
    param.value = i/42.0 * 5000
    # add the parameter to the process
    process.parameters.add(param)

# update the process in the database
olca.updateProcess(process)
```

11.2.5 Running Calculations

In the following example the product system "dung slab" is calculated with the LCIA method "CML 2001" and the results are written to the console (if you are not sure which methods you can call on a result type, just call the *inspect* method of the *olca*-object with the result type as parameter):

```
result = olca.calculate(
    olca.getSystem("dung slab"),
    olca.getMethod("CML 2001") )

for i in result.totalImpactResults:
  log.info("LCIA category = {}, result value = {}, unit = {}",
           i.impactCategory.name, i.value, i.impactCategory.referenceUnit)
```

By using the Python standard library we can easily export our results to a CSV file:

```
# import the Python CSV module
import csv

# calculate the product system
result = olca.calculate(
    olca.getSystem("dung slab"),
    olca.getMethod("CML 2001") )

# open the export file
f = open('C:/Users/Besitzer/Desktop/results_out.csv', 'wb')
writer = csv.writer(f)

# write the results to the file
for i in result.totalImpactResults:
  row = [i.impactCategory.name, i.value, i.impactCategory.referenceUnit]
  writer.writerow(row)
```

```
# close the file
f.close()
```

You could now combine the calculation with a parameter modification as described above to make advanced sensitivity analyses with openLCA. Also, the analysis function and Monte Carlo Simulation are available via the olca-object:

```
# run a Monte Carlo Simulation with 10 iterations
system = olca.getSystem("dung slab")
result = olca.simulate(system, 10)

# for each flow write the result of each iteration
for flow in result.flowDescriptors:
  i = 1
  for r in result.getFlowResults(flow):
    log.info("flow: {}, iteration: {}, result: {}", flow.name, i, r)
    i += 1
```

11.2.6 Using more functions from the API

With the scripting interface in openLCA you have full access to all functions in openLCA. The *olca*-object just provides some entry points to the API. The full API documentation of the core openLCA modules is available on our Github repository: http://greendelta.github.io/olca-modules/. The picture below shows some method declarations in the API documentation of the Process class. These methods are the same as the *inspect* method will print when you call it with a process object as parameter.

Method Summary

All Methods | Instance Methods | Concrete Methods

Modifier and Type	Method and Description
Process	clone()
List<AllocationFactor>	getAllocationFactors()
List<ProcessCostEntry>	getCostEntries()
AllocationMethod	getDefaultAllocationMethod()
ProcessDocumentation	getDocumentation()
List<Exchange>	getExchanges()
byte[]	getKmz()
Location	getLocation()
List<Parameter>	getParameters()
ProcessType	getProcessType()
Exchange	getQuantitativeReference()
boolean	isInfrastructureProcess()
void	setDefaultAllocationMethod(AllocationMethod method)
void	setDocumentation(ProcessDocumentation documentation)
void	setInfrastructureProcess(boolean infrastructureProcess)
void	setKmz(byte[] kmz)
void	setLocation(Location location)
void	setProcessType(ProcessType processType)
void	setQuantitativeReference(Exchange quantitativeReference)

Figure 95: Method declarations in API documentation

In order to use a class in your script you need to import it. There is for example a class *CategoryPath* available in the package *org.openlca.io* which translates a category hierarchy in openLCA into a string path. The following script shows how you could use this class in a Python script:

```
# import the class
```

```
import org.openlca.io.CategoryPath as path

# load a process
process = olca.getProcess("compost plant, open")

# print the full category path of the process
log.info(path.getFull(process.category))

# print the short category path of the process
log.info(path.getShort(process.category))
```

And here is the same in JavaScript:

```
// import the class
var path = Java.type('org.openlca.io.CategoryPath');

// load a process
var process = olca.getProcess("compost plant, open");

// print the full category path of the process
log.info(path.getFull(process.category));

// print the short category path of the process
log.info(path.getShort(process.category));
```

For the core model classes you do not need to add import declarations. So you can directly write the following to create a new process object in Python and inspect it (see also the parameter example above):

```
process = Process()
olca.inspect(process)
```

And in JavaScript:

```
var process = new Process();
olca.inspect(process);
```

Finally, the following picture shows the classes and the dependencies between these classes of the core model:

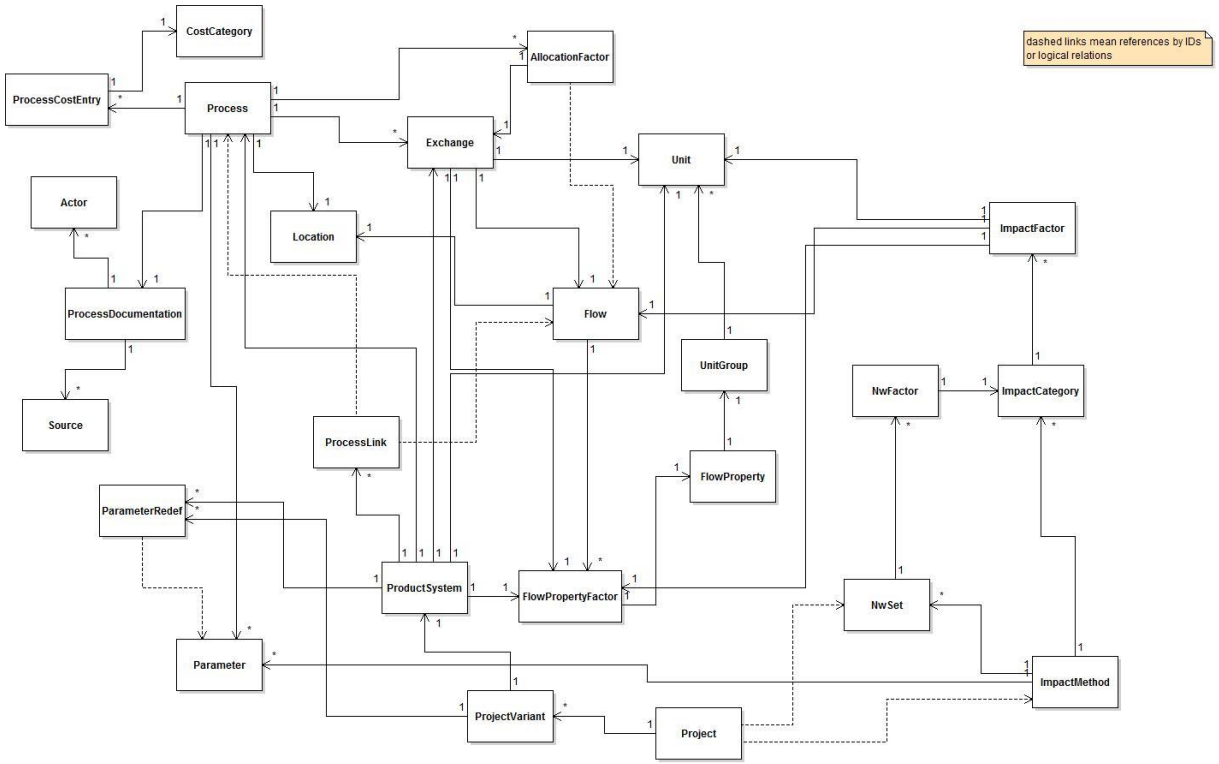


Figure 96: Classes and dependencies of core model

12 Quality assurance and performance

12.1 Quality assurance

In the development of openLCA 1.4, extensive tests were performed to verify and validate the software algorithms and overall usage, also by external testers, e.g. by our Italian partner, be-LCA (www.be-LCA.com). Tests have been performed for example to check, among others, openLCA results versus SimaPro calculation results and openLCA results versus ecoinvent system process results. Further, 'constructed' use cases have been used to reflect specific modelling aspects of LCA (allocation, system expansion, uncertainty calculation, parameter usage,etc.) which have been calculated in other software systems, including Matlab / Scilab and excel. Here is not the space to fully explain all the tests, but we would like to illustrate some of our more relevant results. More information is available on request (see contact information).

Figure 97 shows a comparison of inventory results for SimaPro and openLCA, for the process electricity production mix high voltage, country mix, BE, for ecoinvent 3.0.1, default allocation model. Only those flows are considered where flow names and compartments are identical between SimaPro and openLCA, which is the case for more than 700 flows for the said system. The models were calculated in both software systems, and then exported from SimaPro via text export (which is limited to exponent and two digits) and from openLCA via excel export.

As the figure shows, results are very similar. The most extreme ratios are still very close to 1 meaning that both software systems calculate almost fully identical results:

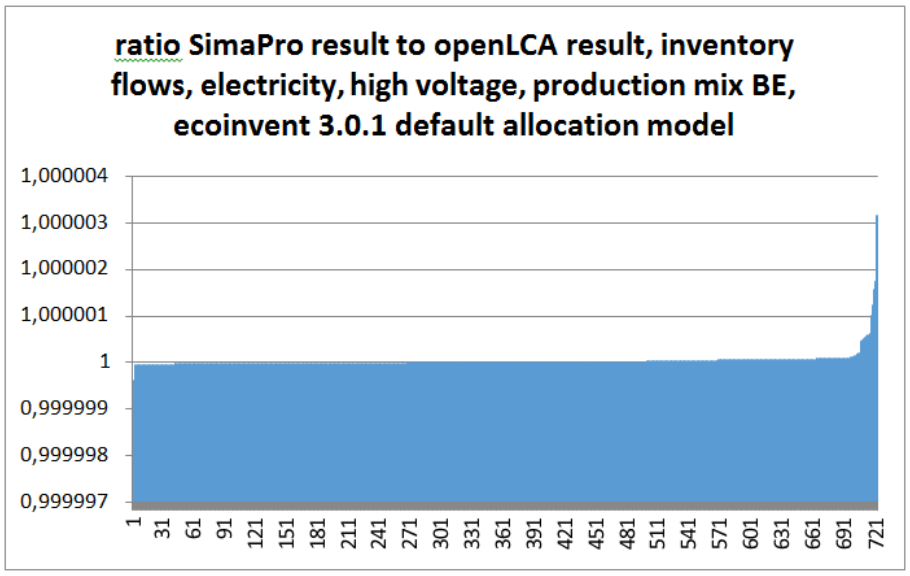


Figure 97: Comparison of inventory results for SimaPro and openLCA

Top 5 minimum ratios are shown in table 1; table 2 shows the top 5 maximum ratios:

Table 1: Ratio of results from SimaPro and openLCA in a calculation comparison, 5 lowest

Input	Category	Sub-category	Flow_name	ratio_SP_to_openLCA
ja	resource	land	Transformation, to unknown	0.999999629
ja	resource	land	Transformation, from mineral extraction site	0.999999816
nein	soil	agricultural	Carbaryl	0.999999946
nein	air	high population den	Ethane	0.99999995
nein	soil	agricultural	Nicosulfuron	0.999999953

Table 2: Ratio of results from SimaPro and openLCA in a calculation comparison, 5 highest

Input	Category	Sub-category	Flow_name	ratio_SP_to_openLCA
ja	resource	in ground	Gallium	1.000001574
ja	resource	land	Transformation, to forest	1.000001739
ja	resource	land	Transformation, to shrub land, sclerophyllous	1.000001744
ja	resource	land	Transformation, from dump site, inert materia	1.000003167
ja	resource	land	Transformation, to dump site, inert material la	1.000003167

This is result of a life cycle calculation with about 7,500 unit processes included.

12.2 Performance

Improving the performance also for large life cycle systems was one of the core tasks in the development of openLCA 1.4. Table 3 presents some results (Windows 64 bit version, Windows 8.1, identical, modern notebook computer, calculation of the inventory only), also in comparison to SimaPro 8.

Table 3: openLCA and SimaPro performance comparison in network/analysis calculation

	Time required [seconds]		Ratio: required time
	openLCA 1.4	SimaPro 8.0.3	SimaPro / openLCA
Ecoinvent 3.0.1 default allocation horn meal production RoW			
Creating a product system*	10.17		*
Analysing / calculating a product system*	34.26		*
Total**	44.43	95.35	2.17
Ecoinvent 3.0.1 default allocation electricity high voltage production mix BE			
Creating a product system*	10.17 (2nd time: 4.18)		*
Analysing / calculating a product system*	33.03		*
Total**	43.20	86.52 (2nd time: 21.73)	2.00

* not available in SimaPro as separate action, always performed when calculating a network in SimaPro

** for openLCA, addition of time for creating and calculating the product system; opening an already created product system in openLCA takes about one second.

SimaPro is used as a benchmark here since it is the only other broadly used LCA software system (at least to our knowledge) that is able to calculate large unit-process based product systems from ecoinvent 3 so far. For the performance tests, the identical computer was used, no other user was interfering with the SimaPro multi-user Developer version; in openLCA, the 'analysis' calculation option was selected which produces results similar to the network calculation in SimaPro which in turn was used for SimaPro.

The table shows that openLCA is at least twice as fast as SimaPro when calculating a large ecoinvent unit process life cycle. This is also shown in the figure below. Both software systems become faster when repeating identical tasks, e.g. when the same product system is deleted and created again, due to caching procedures; in SimaPro, especially a repeated calculation is finished much quicker. In openLCA, a once created product system can be stored; reopening it takes only about one second and saves the time for recreating it. openLCA offers a further 'quick results'calculation were only main contributors and inventory and impact assessment tables are calculated; this quick calculation is about twice as fast as the analysis calculation (e.g., 17.59 seconds for the electricity product system above).

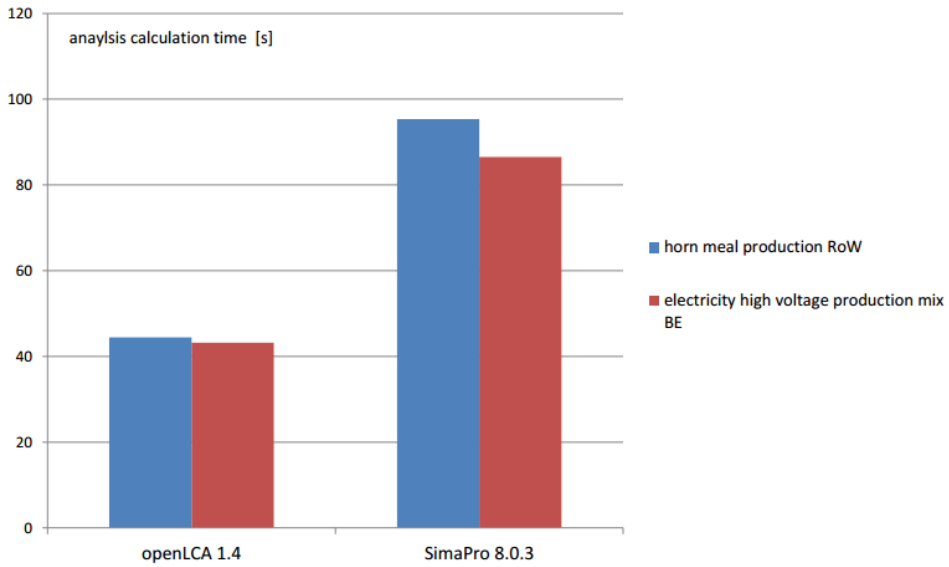


Figure 98: Calculation time comparison between openLCA 1.4 and SimaPro 8.0.3

13 Contact

openLCA is developed and managed by GreenDelta in Berlin. If you have any feedback, comments, questions, please let us know.

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14 Big Thanks

Finally - big thanks to our supporters and contributors. For the 1.4 version, especially the following institutions provided financial support (incomplete overview):